PROGRAM
For
TECHNICAL CONFERENCE FOR
REA FIELD ENGINEERS (ELECTRIC)

January 17 - 21, 1955

Morrison Hotel
Chicago, Illinois

The entire program is based on topics requested by REA Field Engineers. The program was developed by the Program Committee for Electric Engineering Training: John F. Atkinson, Chairman, G. L. Woodworth, R. P. Stokely and Hans Hoiberg.

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

MONDAY, JANUARY 17

Morning Session*

Hollywood Room

R. P. Stokely, Presiding

Opening Remarks . . . . Wade M. Edmunds

Operations and Maintenance Program to Date (Distribution). G. K. Ditlow and C. J. Waldron

Afternoon Session

Hollywood Room

E. E. Warner, Presiding

Findings of Material and Equipment Performance Survey . . . . C. J. Waldron

Recent Action of the Technical Standards Committees . . . . J. N. Thompson

* Registration will begin at 9:00 A. M. - and the Monday Morning Session will start at 10:00 A. M.

TUESDAY, JANUARY 18

Morning Session

Hollywood Room

George H. Cole, Presiding

Pole Inspection and Maintenance. . . . . C. H. Amadon

Afternoon Session

Franklin Park, Illinois

Timber Treating Plant Inspection Trip *. . . . . Courtesy of Joslyn Manufacturing and Supply Company.

Chartered Busses will leave Morrison Hotel at 1:00 P. M. for Joslyn Pole Yard and Treating Plant.

* A timber treating plant is essentially an outdoor operation. In view of the January Chicago weather it would appear advisable for participants to provide themselves with galoshes and extra warm clothing.

WEDNESDAY, JANUARY 19

Morning Session

Hollywood Room

E. L. Arnn, Presiding

Elements Affecting Construction of
Power Plants . . . . Ivan A. Bosman

Internal Combustion Engines and Their
Use in Generating Electric Power . . . . E. J. Raushenberger

Afternoon Session

Hollywood Room

G. L. Woodworth, Presiding

The Functions of a Pre-Loan Engineer . . . . Sam Shiozawa
Mr. Shiozawa's Paper will be presented by J. K. Taylor.

Operation and Maintenance of Electric
Generating Plants . . . . W. E. Rushlow

THURSDAY, JANUARY 20

Morning Session

Hollywood Room

R. P. Stokely, Presiding

Voltage and Current Measurements on Rural Distribution Systems . . . . R. W. Schlie

Selection of Metering for Wide Range Application . . . . H. W. Kelley

Afternoon Session

Hollywood Room

John H. Rixse, Jr., Presiding

D. C. and A. C. Calculating Boards . . . . John G. Hieber

The afternoon session will adjourn early in order to allow ample time for participants to eat dinner and to assemble for the evening session at Illinois Institute of Technology.

Evening Session - 7:30 P. M.
at
Illinois Institute of Technology

John H. Rixse, Jr., Presiding

Demonstration of a Modern A. C. Calculating Board . . . . Dr. E. R. Whitehead
Illinois Institute of Technology

FRIDAY, JANUARY 21

Morning Session

Parlor D

J. E. O'Brien, Presiding

Headquarters Buildings, Design, Construction and Maintenance . . . . H. F. Mabbitt

Mr. Mabbitt's Paper will be presented by James U. Owens. Following Mr. Owen's presentation there will be a period for general discussion, questions and answers, suggestions for topics and meeting place for next year's program.

Conference will adjourn at 1:00 P. M.

NOTES

A REVIEW OF OPERATIONS AND MAINTENANCE SURVEY REPORTS

By George K. Ditlow and
C. J. Waldron, both of
Electric Engineering Division

Presented at the Technical Conference
For REA Field Engineers, Chicago, Illinois
January 17 - 21, 1955.

REA

RURAL ELECTRIFICATION ADMINISTRATION • U. S DEPARTMENT OF AGRICULTURE

A REVIEW OF OPERATIONS AND MAINTENANCE SURVEY REPORTS

George K. Ditlow C. J. Waldron

The basic responsibility for carrying out an adequate program of system operation and maintenance rests with the borrower. However it is REA's responsibility to assure that the physical plant which secures the Government loan is adequately maintained and that reliable electric service is available to consumers. It is necessary therefore, that inspections be made to determine the effect the condition of the borrower's plant may have on loan security. The policy and procedure are specifically outlined in REA Bulletins 100-4 and 161-5R1. The related Staff Instructions 100-1R1 and 161-1R1 outline the procedure of making the engineering review which is a part of the overall appraisal of the financial stability of borrowers.

In order to determine the general status of the physical condition of the REA borrowers' plants a summary of reports of the general inspections available in the Area Offices has been prepared. This was done by taking the results of the inspections as tabulated on REA Form 300 submitted in accordance with Staff Instruction 161-1R1. These results, together with consideration of observations by the field engineers in the narrative part of the report, should be adequate to give a general appraisal of the average condition of the utility plants of the REA borrowers.

ANALYSIS OF REPORTS OF GENERAL INSPECTIONS

The result of an overall summary of reports of inspection on 54 borrowers is shown in the accompanying Table I. An average of approximately 4½ days was spent on these inspections. It is not known, however, whether or not the time required for writing the report was included as this was not indicated in most cases. As a matter of interest a total of approximately 286 general inspections and 55 comprehensive inspections and detailed appraisals have been made as of October 1954. In the table mentioned above values have been assigned to the ratings shown on Form 300 as follows:

Excellent	100
Very Good	90
Good	80
Fair	70
Poor	60

It was considered that values less than 60 would be intolerable due to membership objections to inadequate service and this would require the borrower to make necessary improvements. Numerical values were used for summary purposes. For making individual evaluations during inspections, however, the following might be considered:

Excellent -- New (Probably 3 years or less depending on the items being checked)
Very Good -- Better than Normal
Good -- Normal (Means average depreciation and in average state of repair)

Fair -- Below Normal
Poor -- Unsatisfactory (Immediate action necessary)

Comments should be included in the body of the report to substantiate the above evaluations.

Table II is a summary on the basis of individual borrowers. Table I is an overall summary and appears to show somewhat higher rating for the physical condition of equipment than that for the condition of construction. This slight difference is not a matter of great concern, but should be recognized in giving suggestions to the borrower leading to better construction practices. A similar tabulation for operation and maintenance activity or progress for the same borrowers, not included in this paper, indicated similar relative values.

Since relatively high values are indicated in the analysis of forms 300 for plant condition and operation and maintenance activity it would seem that the condition of plant may not be of greatest concern at the present time, considered from a loan security standpoint. As the systems become older any deficiency in the condition of physical plant, due to lack of maintenance, will become more apparent.

Table III contains a rearrangement of the items listed in Table I with relative values in ascending order. It is seen that even the two worst items, right-of-way and pole top hardware, have a rating of 80, equivalent to "Good" on Form 300. Substation condition is the best with a numerical rating of 92 or better than "Very Good."

It should not be inferred from a study of the tabulations that the existing operational activity in general is adequate in all respects or not important. On the contrary, a systematic program should be continued or developed to avoid the building up of deferred costs which may become an unexpected burden to our borrowers in the future.

The narrative parts of the reports on general inspections do not show any general relationship between financial status of the borrowers and plant condition except possibly for right-of-way. Even in this category the reports do not indicate that the costs of deferred clearing of right-of-way would be a major factor in the matter of loan security.

A clear relationship between operation and maintenance activity and the physical condition of plant is not indicated. It is obvious that such a relationship must exist and that it would be more clearly in evidence on the older systems and those with more serious right-of-way problems.

The summary indicates a general satisfactory condition of plant. This is to be expected, since the average weighted age of the borrowers used in the summary is about 9 years. Older systems will tend to be in poorer average condition, particularly where maintenance activity is below average. The average weighted age for all borrowers is 8 years.

The average replacement rate for components of distribution lines can be expected to rise steadily to about 4 or 5 times the present value during the next 15 years, judging from studies that have been made on comparable equipment. The basis for this

conclusion is described in the Appendix, which also contains typical replacement and total renewal curves for utility components.

COSTS OF OPERATIONS, MAINTENANCE AND REPLACEMENT

A spot check was made of a considerable number of operating reports of distribution systems to determine the average costs of operations and maintenance. This check indicates that costs chargeable to operations are approximately 1.4% of the original cost of plant and those for maintenance approximately 0.8%. It is believed that the cost of operation probably will not increase materially; however, the costs of maintenance will probably rise with the age of the plant.

The costs of replacement of plant cannot be accurately determined under our present accounting system. Perhaps replacement costs should be identified and opinions regarding this point will be appreciated.

OUTAGE DATA

A spot check was made of 40 random reports to determine information supplied on outage data or outage records. Generally information on one or both was given, but outage data, per se, were given in only 8 of the 40 cases.

Eight borrowers were reported as having no outage records; of these one had formerly kept records but abandoned them. Of the 32 borrowers reported as keeping outage records, 7 had incomplete records and 4 were reported as making no use of the data recorded.

It appears that borrowers are to a great extent overlooking the importance of using outage records. Such records as outlined in REA Bulletin 161-1 provide much information on operating practices and service to consumers. However, it is recommended that borrowers be urged not only to keep outage records but analyze and interpret the data and effect such remedial measures or changes in operating practices as are indicated necessary.

ADEQUACY OF GENERAL INSPECTIONS

In reviewing the narrative part of a considerable number of general inspection reports we believe that most of the reports are adequate. A few suggestions may be in order. It should be kept in mind that, during the making of the inspection and the writing of the report, the primary objective is an estimate of the physical condition of the elements of construction in the physical plant. The estimate should result in an expression of opinion as to the effect of this condition on the loan security status of the system. This is especially important if an unusual deficiency is noted in any construction procedures or materials, operations, and above normal maintenance or replacement costs.

Below are given examples of reports which bring out facts pertinent to the particular situation:

"1 -- Right-of-way

An extensive program is in effect to reclear right-of-way using chemicals and recutting. Particular attention is being paid to widening the right-

of-way whenever it is recut, with the idea of a minimum of thirty feet at the top. Basal spray, foliage spray, and dormant application are all used as necessary. Very good records are maintained of this operation which show the cost and progress of the job. To record progress, a key map has been marked in color to indicate by year and by symbol the type of treatment. This record shows that most of the system has been treated from one to three times since 1952. The actual and estimated expense for right-of-way is as follows:

Actual 1953	$50,000.00
Estimated 1954	60,000.00
" 1955	60,000.00
" 1956	30,000.00
" 1957	30,000.00

According to my observations the program is well coordinated, effective and is being done at a reasonable cost."

"3 -- <u>Pole Top Assemblies</u>

A. "The pole top assemblies which were inspected showed little evidence of loose hardware and no bent pins were observed. Ground wire placement was satisfactory and this condition was borne out by the unusual absence of radio interference from primary lines.

B. "The crossarm assemblies were generally good as to cant and leveling. The manager informed us that he had obtained very poor service from creosoted pine crossarms generally obtainable in the area. He said that in his opinion the treated pine arms did not give as good service as the untreated fir arms and this was due to the poor quality of the timber.

C. "Very few insulator failures have been reported recently from chipping and practically no contamination is experienced in the area. Some previous failures have been found caused by gun fire."

Reports similar to the above illustrate how judgment can be used in presenting salient facts and pertinent observations. In the case of the report on right-of-way, however, it would be necessary to supplement the cost figures given to determine the cost required to place all right-of-way in "Good" or better than "Good" condition as outlined in Staff Instruction 161-1R1, section D paragraph 2g.

The sample report on pole top assemblies calls attention to a possible serious problem of crossarm replacement. It would be in order when problems of this nature are discovered to give an opinion in the report as to the possible effect this may have on the financial status of the borrower.

At this point we would like to make a few observations based on the reports analyzed during the past year. They are:

1. Many do not indicate the total time spent, that is; time spent at borrower plus report writing and typing time.

2. Many reports do not indicate who prepared Form 300.

3. Perhaps reports should indicate lines inspected, age and location for office reference and for use by the field engineer on the next inspection.

4. Some reports do not indicate on Form 300 the number of miles in the section being evaluated.

5. Certain field engineers have specialties which are reflected in the reports. Every attempt should be made to be objective.

6. Few reports refer to prior inspections. Are previous inspection reports available?

7. Perhaps more emphasis should be placed in the report on conditions rated fair and poor.

8. Many reports do not indicate the type of terrain in which the system is operating and other operating problems.

We would also like to pose several questions:

1. Howe much time should be spent on general inspections? Average on the 54 general inspection reports is about $4\frac{1}{2}$ days. The size of the system seemed to make little difference. In this regard the status of the work on sampling techniques will be discussed.

2. To what extent are borrowers cooperating and supplying the information requested in REA Bulletin 161-5R1?

3. What guide lines should be used in arriving at adjective ratings of the physical condition of the plant?

4. Present procedure probably results in many cases in a compromise Form 300 between field engineer and the manager. Should two Form 300's be submitted?

5. Do you think more emphasis should be given to older portions of the system during inspection?

6. Do you have any suggestions on the scheduling of general inspections?

7. Do you think Form 300 should be revised?

We would appreciate, preferably in writing, any comments or suggestions you may have with respect to the observations and questions which have been listed above.

Since there is a limited number of available REA field personnel, there are no doubt cases where general inspections of all systems cannot be made within a reasonable time. Therefore assignments of personnel for such work is being made selectively. The analysis of the general inspection reports shows that usually the selection of borrowers for a general review to be made by the field engineer may best be determined as outlined in Staff Instruction 100-1R1 assigning greatest importance to items A and B of Section II. This would automatically give priority to consideration of a comprehensive inspection and detailed appraisal for those borrowers having loan security problems.

It is assumed that during the course of a general inspection many constructive suggestions would be developed jointly by the manager of the system and the field engineer leading to economies in operations and maintenance of the physical plant and more effective method of maintaining satisfactory electric service to the members. While this a worthy objective it should not be allowed to obscure the primary objective which is the review of the physical plant. Due to the time element it may be necessary to postpone detailed recommendations for changes in the borrower's methods and procedures to a later visit or to the time when a comprehensive inspection and detailed appraisal is made.

CONCLUSIONS

The analysis of reports of general inspections of borrowers' electric systems indicated the following:

1. Physical plants are generally in "Very Good" condition. A higher correlation of condition with operations and maintenance activity would probably exist if the plants were older.

2. It is certain that maintenance and replacement costs will increase as equipment becomes older. It is likely that an increase in amounts for these items in future operating budgets will be necessary.

3. Due to the large number of general inspections still to be made and the limited number of available REA field personnel priority may have to be given to borrowers in financial straits.

4. Most reports on general inspections were satisfactory. They generally included details on physical plant condition and operations and maintenance activity (together with Form 300); estimated costs of operation; estimated costs of maintenance, replacements for the next two years; and information concerning unusual items of plant, equipment or service. With respect to the quality of service the reports were generally adequate on the subject of voltage conditions, however there was an absence of information as to continuity of service. This latter was no doubt due to the fact such information was not available from the borrowers.

TABLE I

Summary of Data on Condition of Physical Plant Reported on Forms 300 with 54 Inspection Reports

	Item	Number of Borrowers, Physical Plant Condition E	VG	G	F	P	Average Numerical Rating
1	Right-of-way	6	16	12	12	8	80
2A	Poles, Installation	12	23	17	2	0	88
2B	Poles, Condition	14	21	16	3	0	88
3A	Pole Top Assemblies, Hardware	10	16	17	9	2	80
3B	Pole Top Assemblies, Crossarms	17	18	17	2	0	89
3C	Pole Top Assemblies, Insulators	18	26	5	3	0	91
4A	Guys and Anchors, Installations	9	23	18	4	0	87
4B	Guys and Anchors, Condition	19	22	10	3	0	91
5A	Primary Conductor, Installation	12	21	16	3	1	88
5B	Primary Conductors, Condition	20	22	11	1	0	91
6	Secondaries and Services	15	14	16	5	4	86
7A	Substations, Installation	17	14	7	3	1	90
7B	Substations, Condition	22	10	8	2	0	92
8A	Dist. Transformers, Physical Condition	6	18	22	7	0	84
8B	Dist. Transformers, Electrical Condition	12	21	18	3	0	88
9	Automatic Sectionalizing Devices	13	19	16	3	1	88
10	Fused Cutouts	9	19	16	3	1	87
11	Air Break Switches	15	14	14	0	0	90
12	Meters	18	16	10	3	0	90
13	Two-Way Communications Equip.	13	22	14	3	0	89
14	Freedom from Radio Interference	6	17	22	4	1	85
15	Rolling Stock	15	23	12	2	0	90
16	System Grounds	6	15	23	4	1	84
	Total	304	430	337	84	20	

TABLE II

Summary of Data by Borrower on Condition of Physical Plant Reported on Forms 300 with 54 Inspections Reports

System No.	Terrain	Miles	Weighted Avg. Mos.	Condition of Plant	O & M Activity	No. days for Report	Adequacy of Report
1	Rolling	2000	106	96	92	7	E
2	Rolling	910	120	95	89	5	E
3	Rolling	2720	107	89	97	5	E
4	Rolling	770	80	99	99	5	VG
5	Hilly	580	100	95	95	5	VG
6	Rolling	1700	94	96	97	5	VG
7	Rolling	2250	98	95	94	5	VG
8	Hilly	850	98	98	96	5	VG
9	Hilly	158	111	84	77	4	VG
10	Hilly	620	480+	91	83	10	VG
11	Hilly	200	128	85	80	4	VG
12	Hilly	820	140	92	88	4	E
13	Rolling wooded	2213	101	92	93	5	VG
14	Rolling	1578	162	99	100	4	VG
15	Rolling	402	159	83	88	5	VG
16	Rolling	351	158	81	79	5	VG
17	Rolling	1049	145	83	92	5	VG
18	Rolling	1415	126	86	83	3	G
19	Rolling	1450	96	85	78	5	E
20	Rolling	1620	102	80	80	6	VG
21	Rolling	1000	101	79	80	6	VG
22	Level	689	61	99	95	5	VG
23	Rolling	1186	110	90	85	5	G
24	Rolling	1790	102	89	80	7	VG
25	Rolling	950	84	90	94	5	G
26	Rolling	1622	98	92	95	4	VG
27	Rolling	1800	94	83	82	5	G
28	Rolling	2719	43	91	88	4	VG
29	Level	2826	109	90	90	3	G
30	Rolling	2409	69	91	85	3	VG
31	Rolling	2400	72	90	90	4	VG
32	Rolling	1800	79	91	87	3	VG
33	Rolling	3158	80	95	74	4	G
34	Hilly	860	100	77	76	4	G
35	Hilly	933	143	87	83	5	VG
36	Hilly	1685	99	82	83	5	VG
37	Hilly	1157	148	82	82	4	VG
38	Rolling	2390	114	82	79	4	VG
39	Rolling	1213	100	78	77	5	VG
40	Rolling	2160	81	92	87	4	G
41	Rolling	977	66	87	88	5	VG
42	Rolling	715	151	86	84	2	G
43	Level	1120	145	86	87	4	G
44	Level	1754	59	88	85	2	G
45	Level	2566	87	86	80	4	F
46	Rolling	1211	122	88	92	2	F
47	Hilly	1932	45	88	85	3	F
48	Rolling	1512	56	86	90	3	F
49	Rolling	2348	107	85	89	2	G
50	Rolling	361	79	90	90	2	F
51	Hilly	500	85	84	83	4	G
52	Hilly	335	86	85	82	5	G
53	Rolling	335	143	83	88	4	VG
54	Rolling	1460	139	90	90	4	G
	AVERAGE	1400	110.5			4.4	VG

TABLE III

Relative Ratings of Condition of Physical
Plant Listed in Table I

Item		Average Numerical Rating
1	Right-of-way	80
3A	Pole Top Assemblies, Hardware	80
8A	Distribution Transformers, Physical Condition	84
16	System Grounds	84
14	Freedom from Radio Interference	85
6	Secondaries and Services	86
4A	Guys and Anchors, Installation	87
10	Fused Cutouts	87
2A	Poles, Installation	88
2B	Poles, Condition	88
5A	Primary Conductor, Installation	88
8B	Distribution Transformers, Electrical Condition	88
9	Automatic Sectionalizing Devices	88
3B	Pole Top Assemblies, Crossarms	89
13	Two-Way Communication Equipment	89
12	Meters	90
7A	Substations, Installation	90
11	Air Break Switches	90
15	Rolling Stock	90
3C	Pole Top Assemblies, Insulators	91
4B	Guys and Anchors, Condition	91
5B	Primary Conductors, Condition	91
7B	Substations, Condition	92

APPENDIX

REPLACEMENT RATE VERSUS AGE

Replacement rates vary with age of equipment. The relationship of replacement rates to age has received extensive study so that we can make a rough estimate as to what may be expected.

Figure 1 shows typical curves of replacement rates as related to age of certain kinds of industrial equipment. These are three type curves (selected from a total of 18) developed from actual experience in studies published by the Iowa Engineering Experiment Station in 1935. Curve L_2 approximates the most usual experience with electric, telephone and telegraph poles. Curve S_0 is the one nearest the average experience with distribution transformers, although the actual curve shapes were quite variable. Curve R_4 represents the most typical experience with watthour meters and also approximates the data from one study of overhead electrical conductors.

The curves of Figure 1 show trends applicable to replacement of original units only, excluding replacement of replacements, and therefore each curve eventually returns to zero ordinate.

For purposes of this discussion, let us assume that the overall replacement rate for components of a distribution system would approximate the average of the three curves of Figure 1. Let it be further assumed that the average life of equipment is 30 years so that replacement rates can be expressed in percentage per year. The resulting relationship is shown in Figure 2. Curve B shows the average frequency of replacement of original components installed at the time zero on the time axis. Curve A shows the total replacement curve, including the replacement of replacements, for the same conditions assumed in Curve B.

The relationships of Figure 2 may be subject to considerable variation in any particular case, but the curves represent what is probably the best evaluation of experience now available. The trend that is represented is an important one to consider when estimating probable future replacement costs and rates of plant deterioration.

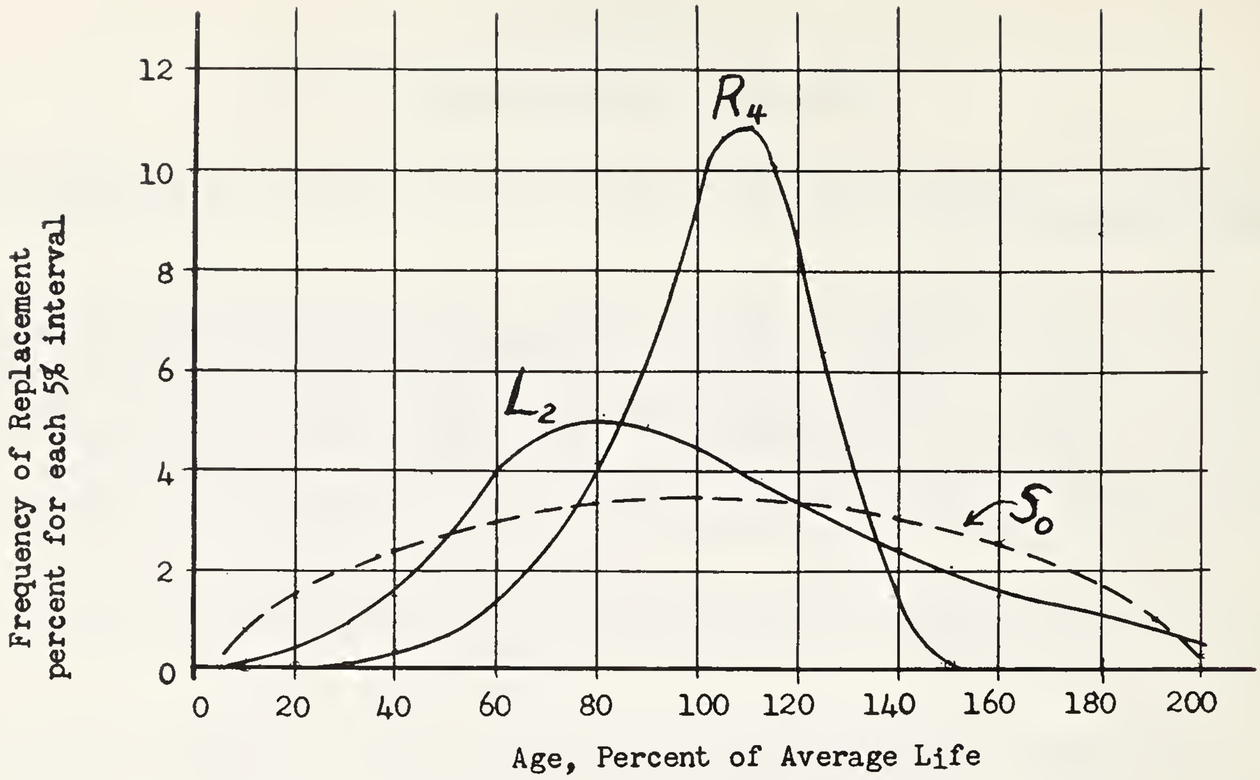


Figure 1--Replacement Rates As Related to Age
for Industrial Equipment

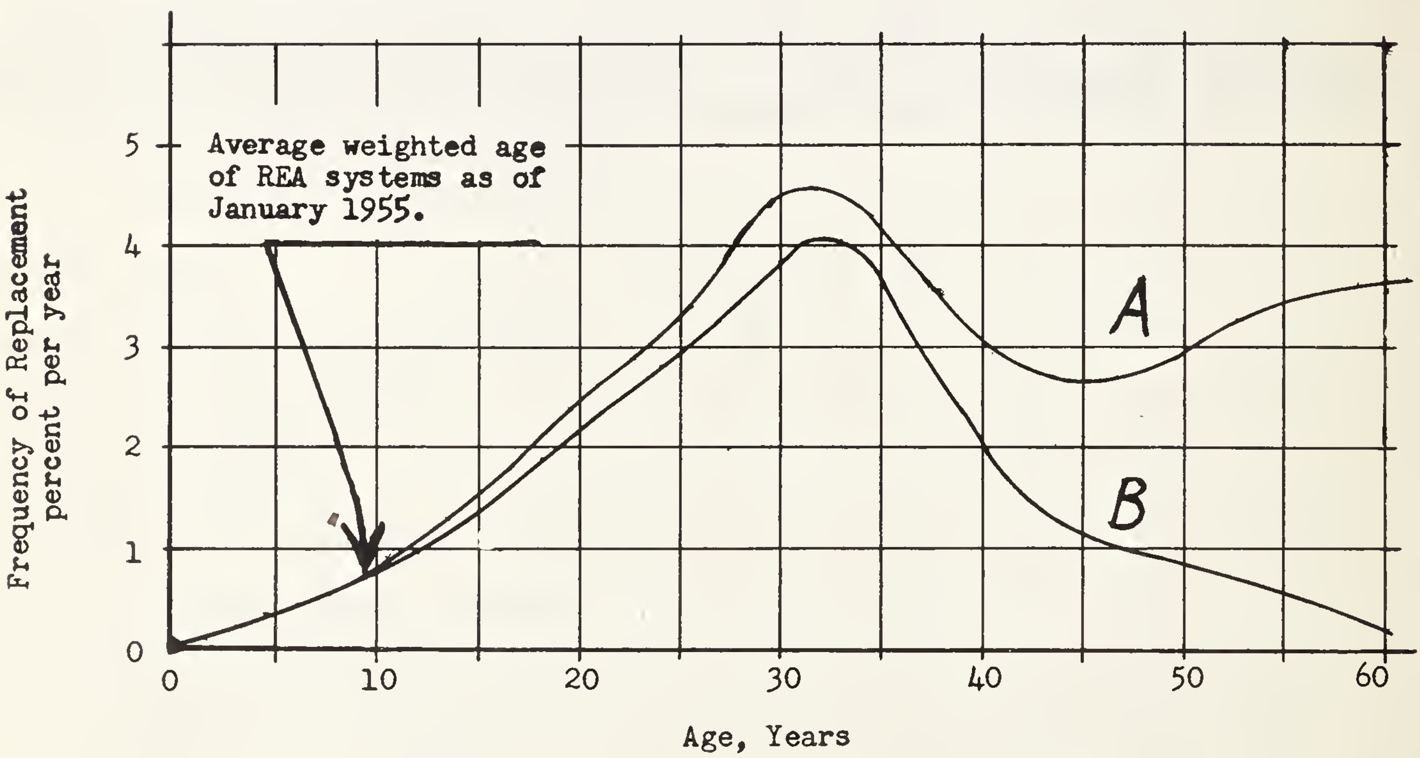


Figure 2--Replacement Rates (Curve B) and Total
Renewals (Curve A) as Related to Age,
for 30 Years Average Life.

FOR DISCUSSION PURPOSES ONLY.
This paper in its present form does not necessarily represent official REA policy or procedures.

FINDINGS OF MATERIALS AND EQUIPMENT PERFORMANCE SURVEY

By C. J. Waldron
Electric Engineering Division

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
January 17 - 21, 1955.

REA

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

FINDINGS OF MATERIALS AND EQUIPMENT PERFORMANCE SURVEY

C. J. Waldron

INTRODUCTION

This paper describes the recent progress and findings from the Materials and Equipment Performance Survey. Future plans and help needed from field people are discussed.

PROGRESS IN HANDLING FIELD DATA

Our greatest concern is one that has been indicated on several occasions -- the problem of minimizing the time lag between receipt of failure report data and the distribution of findings to borrowers.

The biggest obstacle in the past was the development of data processing methods to adequately interpret the thousands of failure reports that enter into each analysis. This development work has been completed. Present problems may not be smaller, but at least they're different.

The major hurdles to overcome now are:

1. The production work of coding, machine processing, interpretation of findings and writing, review and publication of reports. This is largely the problem of the Washington staff.

2. The problem of getting better information from the field, with respect to --

   a. Complete reporting of all failures.

   b. Data on quantities of equipment in service.

   This is a matter in which the participation of the field staff will be important.

RECENT FINDINGS

Pin Insulators

The increased resistance to lightning damage of flared type insulators as compared with high type insulators is further verified in the September 1954 report that has been distributed to borrowers.

Of particular significance is the fact that 33 percent of all failures were attributed to shooting or rock throwing. This emphasizes a need for education of the public to the consequences of such malicious actions as well as a need for insulators with greater resistance to impact. It is probable that some insulator failures reported as caused by shooting or rock throwing actually were caused by lightning. Therefore the 24 percent figure for failures due to lightning may be too low.

Poles

As might be expected, rot was the cause of more pole failures than any other single cause, being 51 percent of the total. Lightning was next and was 18 percent of all those reported. The average age of all poles on which failures were reported was seven years. Most of the pole failure reports were from the midwestern and southern states.

Primary Conductor

Sixty-two percent of all conductor failures were due to physical damage by weather, as is shown in the September 1954 report. Lightning was the primary cause, followed by ice, snow or sleet, with wind third in percent of all failure causes. Almost 75 percent of all failures were reported as complete breaks or burn-offs. The average age of ACSR conductor reported was 5.4 years, of solid copper 7.8 years and of Copperweld and Copperweld-copper 8.0 years.

The reports received provided some interesting data on conductor. Inasmuch as failure rate has not been determined, it is not possible to present conclusive data at this time. In this connection, it should be noted that about 90 percent of the conductor failures were reported by 42 percent of the 101 participating borrowers and approximately 82 percent of the failures were represented by 25 percent of the participating borrowers, located in the midwestern and southeastern states.

Although the reasons for variations in performance of conductor are not clear at the present time, details on quantity of conductor in service, to be obtained in the future, are expected to provide more conclusive information.

The performance of conductor may be affected by the following factors:

1. Physical size of conductor may well be the most important characteristic affecting damage by lightning and undoubtedly is a factor in failure from other causes.

2. Construction specifications differ for different types and sizes of conductor. Some types are protected by armor rods and others may have no protection at hot line clamps where stirrups have twisted or broken.

3. Age of conductor would have some effect on failure rate. Longer exposure to mechanical and electrical stresses would normally tend to cause a higher failure rate in the older installations.

Distribution Transformers

Analysis of failure reports through 1953 indicates that 44.7 percent of the 3998 transformer failures were reported as due to lightning. An additional 14.1 percent were reported as due to overload (8.1) or short circuit (6.0). The cause of failure was unknown or not given in 29.4 percent of the reports.

Failure rate information is being developed as far as possible with the information now on hand. Careful analysis of information from 30 borrowers indicates an average failure rate of approximately 0.9 percent per year. Comparisons according to protection (CSP vs. conventional types) are being developed but are not complete at this time.

Outage Information

Additional to the financial cost of outages due to equipment failure is the impairment of service to the consumer. Table I is extracted from the latest materials and equipment performance report and represents average outage time and number of consumers involved by failures of each of the three items covered.

Table II lists similar data, except that it includes failures only where outages occurred.

TABLE I

Outage Data based on all failures reported on Pin Insulators, Poles and Conductor

Item	Consumers involved	Duration Hr:min	Consumer-hours
Pin Insulators	57	2:20	133
Poles	42	6:30	273
Conductor	104	3:00	312

TABLE II

Outage Data for Failures of Pin Insulators, Poles and Conductor causing Outages only

Item	Consumers affected	Duration Hr:min	Consumer-hours
Pin Insulators	80	3:15	260
Poles	62	9:30	589
Conductor	108	3:05	333

FAILURE RATES AND DATA ON EQUIPMENT IN SERVICE

Equipment failure information increases greatly in value when expressed in terms of failure rates rather than number of failures alone. However, the quantities of each kind of equipment in service must be known or estimated before failure rates are defined. The quantities in service must be further broken down by description of equipment to permit comparisons between such factors as manufacturer, transformer protection, pole preservative, conductor type and size, and model and type of recloser or watthour meter. It has been our experience that adequate information on equipment in service cannot be developed from the information on the failure reports (REA Form 286) alone; for that reason the information on equipment in service will now be requested directly from each participating borrower. A special form and instructions for that purpose have been designed and will be available in final form by January 1955.

Borrowers are not expected to have complete records on all descriptions of equipment. Where records are not complete, the value of a carefully considered estimate is usually much greater than the manager or line superintendent realizes. If each participating borrower supplies the best information available, the resulting data will be entirely adequate.

CONCLUSIONS

The amount of information and the quality of information from the field have become the most important factors affecting the value of findings from the Materials and Equipment Performance Survey. To improve the information on which findings are based, the following steps are planned:

1. Send findings or other follow-up information to all borrowers in the survey at intervals of not more than 90 days, to maintain the interest. Scheduled for distribution in 1955 are:

   a. A report on distribution transformers.
   b. An early report on primary conductors including data on the failure rate.
   c. Follow-up letters to be sent quarterly to all borrowers, showing number of failures reported, for verification by borrowers.
   d. A report on watthour meters (late 1955 or early 1956).

2. Secure information on equipment in service directly from participating borrowers. It is hoped that the questionnaire can be distributed in the first quarter of 1955, so that the information received on conductors can be used in the report on primary conductors referred to above.

3. Arrange for the REA fieldmen to discuss the survey with each participating borrower at regular intervals for the following purposes:

   a. To review for completeness the reports that have been submitted.

   b. To answer questions as to what should be reported as a failure and, if possible, help borrower discover possible omissions.

c. To give assistance when needed for completing "Equipment in Service" reports.

d. To note and report any conditions, such as changes in borrower personnel, which are likely to affect the borrower's participation in the survey.

It is recognized that the interest of participating borrowers has suffered at times because of the lack of published information during the development phase of this study. Findings from the survey and follow-up information will now be sent out at regular intervals. We shall appreciate the assistance of the REA field staff in maintaining borrower interest at a level that will assure complete, accurate reporting of failures.

FOR DISCUSSION PURPOSES ONLY.
This paper in its present form
does not necessarily represent
official REA policy or procedures.

RECENT ACTIONS OF THE TECHNICAL STANDARDS COMMITTEES

By J. N. Thompson
Electric Engineering Division

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
January 17 - 21, 1955.

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

RECENT ACTIONS OF THE TECHNICAL STANDARDS COMMITTEES

J. N. Thompson

The Technical Standards Committees are given the responsibility for accepting all items of material and equipment appearing in the "List of Materials Acceptable For Use on Systems of REA Electrification Borrowers." They are also responsible for the adoption of drawings, construction standards and equipment specifications used by REA. We are concerned only with matters relating to the electric program, since the telephone program has its own Technical Standards Committees.

DRAWINGS

At one time construction drawings made up a large part of the committee's work load but this is no longer the case. During the year ending November 1, 1954, a total of nine new or revised drawings were accepted. These drawings are:

G310-50	Cluster mounting of three transformers
M8-5	Metering guide drawing for above assembly
K16C,K17,K17L	Service assemblies for ranch type houses
M24-10	Metering guide drawing for above assemblies
TH-5R	Revision of transmission drawing TH-5 to permit the use of a standard crossarm
TH-5AR	Similar revision of drawing TH-5A
M8-6) M8-7) M8-8)	Guide drawings for secondary metering, using the new through type current transformers

These drawings, with the exception of TH-5R and TH-5AR are shown in Figures 7 through 13.

SPECIFICATIONS

One phase of the committee's work which is possibly not so well known is the consideration of REA specifications for materials and equipment. We have never made any attempt to write specifications for every piece of material which borrowers may have occasion to use but only for those items for which no suitable nationally-recognized standards exist. When any group such as the American Standards Association, the National Electrical Manufacturers Association, the Edison Electric Institute or the American Wood Preservers Association has a standard which meets our needs and which is recognized by the industry the introduction of an REA specification will serve no useful purpose.

As an example of why we have issued specifications for some items but not for others, let us consider bolts. Machine bolts, carriage bolts and double arming bolts are covered by EEI Specification TD-1. All major hardware manufacturers make bolts in accordance with this specification. Since we are willing to accept these bolts we need merely to specify "bolts in accordance with EEI Specification TD-1" instead of detailing our requirements in six or eight pages of text and drawings. When we come to upset bolts, however, we find that there

has been no recognized standard and that the designs of the various manufacturers have differed widely as to dimensions, type of steel, and strength. An REA specification for upset bolts was prepared, detailing our requirements and setting up a procedure for strength tests. Even this specification has been considerably shortened by the use of references to other specifications. We call for steel to meet ASTM Specification A107, threads and nuts to be in accordance with EEI Specification TD-1, washers in accordance with EEI Specification TD-10, and galvanizing in accordance with ASTM Specification A153.

Possibly the biggest step taken by REA in the standardization field has been in the development of specifications for the component parts of steam generating plants. We believe that this is the first time this has ever been tried and we feel certain that appreciable savings to our power-type borrowers will result. For the first time suppliers will bid on similar equipment and the tedious job of bid evaluation will be largely eliminated.

REA specifications for connectors have recently been issued. It is hoped that enforcement of these specifications will help to eliminate most of the troubles caused by poor connectors.

Other specifications issued during the past year include those for plate anchors for transmission lines, repaired distribution transformers, conduit clevises and wireholders and revisions to the timber specifications.

NEW MATERIALS AND EQUIPMENT

During the past year we have seen a number of new items of equipment and a number of improvements to items already on the list of materials.

Transformer Mounting

One item which has caused a great deal of comment is the transformer mounting bracket made by the Universal Pole Bracket Company. It permits the pole mounting of two or three transformers of sizes up to 100 KVA on a single pole. Figure 1 shows the arrangement of the bracket and Figure 2 shows a dummy installation at the Prince William Electric Cooperative, Manassas, Virginia, which was used in determining the final layout in the construction drawing for this assembly. This is not the first cluster mounting bracket for transformers but it has some advantages over the others, principally in the elimination of gains or additional holes in the pole. It has been given trial acceptance.

Service Cable

Another matter which has received a considerable amount of attention is the deadending of the three-conductor, self-supporting or "Triplex" type of service cable. If we are to build service spans of anywhere near 150 feet and maintain a reasonable ground clearance we must use the type having an ACSR neutral. ACSR cannot be deadended on a conventional wireholder or service spool since it would be bent around too short a radius, spreading the aluminum strands and exposing the steel core to corrosion. The minimum diameter of spool insulator recommended by the conductor manufacturers for this purpose is 1-3/4 inches, this being the most common size of secondary spool. At first we tried to support this spool with a clevis and eyescrew combination but this proved to be too cumbersome and rather expensive. The clevis type wireholders shown in Figure 3 are, we believe, a more

practical way of doing this.

On ranch type houses and other buildings with low roofs there is a problem in making the service attachment high enough from the ground. This is usually handled by means of a pipe mast which also serves as a conduit for carrying the wires into the house. A conduit clevis for use with "Triplex" and a conduit wireholder for deadending single service wires are shown in Figure 4.

Insulators

The Kimble Glass pin type insulator has been given full acceptance for use on 7.2/12.5 KV systems. A post type insulator made by Lapp has been accepted for 14.4 KV use.

Lightning Arresters

New designs of heavy duty arresters using magnetic arc expulsion principles developed by the Ohio Brass Company and the General Electric Company have been given trial acceptance. In the field of expulsion type distribution arresters, Kearney has introduced an entirely new model and Electric Service has modified its "Keystone" arrester. Both are on the trial list.

Regulators

Regulators for use on 14.4/24.9 KV systems have been developed by General Electric and Westinghouse. These are similar to the ML-32 and URL-16 pole type regulators for 7200 volts except that they have 25 KV insulation. Both are on the trial list.

Oil Circuit Reclosers

The only recent significant development has been the introduction of the Kyle Type "R" which is a three-phase, heavy duty recloser. By the use of relays this recloser can be adapted to a variety of conditions and is being used in irrigation areas and other places where three-phase sectionalizing is necessary or desirable.

Cutouts

Several new cutout designs have appeared in the past year, most of them prompted by the need for higher interrupting capacity. "Bird proofing" is also a very popular feature.

Deadends for Guys

In addition to the conventional three-bolt guy clamp several other devices are offered for deadending guys. The Reliable "Strandvise" has been on the list of materials for some time. Two other devices are now on the trial list. One is the Preformed Line Products' "Guy Grip" (Figure 5) which derives its holding power from the spiral wrapping of steel strands around the guy wire. The other is a two-bolt "S" shaped guy clamp (Figure 6) made by the Line Material Company. The offset construction gives it a snubbing action which provides a holding power approximately equal to the larger and more expensive three-bolt clamp.

Connectors

A number of new connector designs have appeared, most of them aimed at providing a simple and effective method of making aluminum-to-aluminum and aluminum-to-copper connections. The general trend is toward the use of aluminum in the body of any connector to be used on aluminum conductor. (This is required in our specifications.) The method of providing a suitable contact for the copper conductor varies. There appears to be a tendency towards greater use of compression connectors such as the Kearney "Squeezon" and Burndy "Crimpit".

POLE PLANTS

The listing of timber treating plants is almost completed. This inspection and listing of plants by REA is not intended to replace the inspection of the timber products themselves by the inspection company. The objective is to eliminate those plants which by reason of inadequate equipment, improper maintenance or poor operating practices either cannot produce properly treated timber or make it impossible for the resident inspector to do a complete inspection job.

Although the number of construction drawings being submitted to the committee has decreased in recent years, the number of applications for listing of new or redesigned equipment remains at about the same level year after year. The "List of Materials Acceptable For Use on Systems of REA Electrification Borrowers" is reprinted each year but supplements are now issued every three months instead of every month.

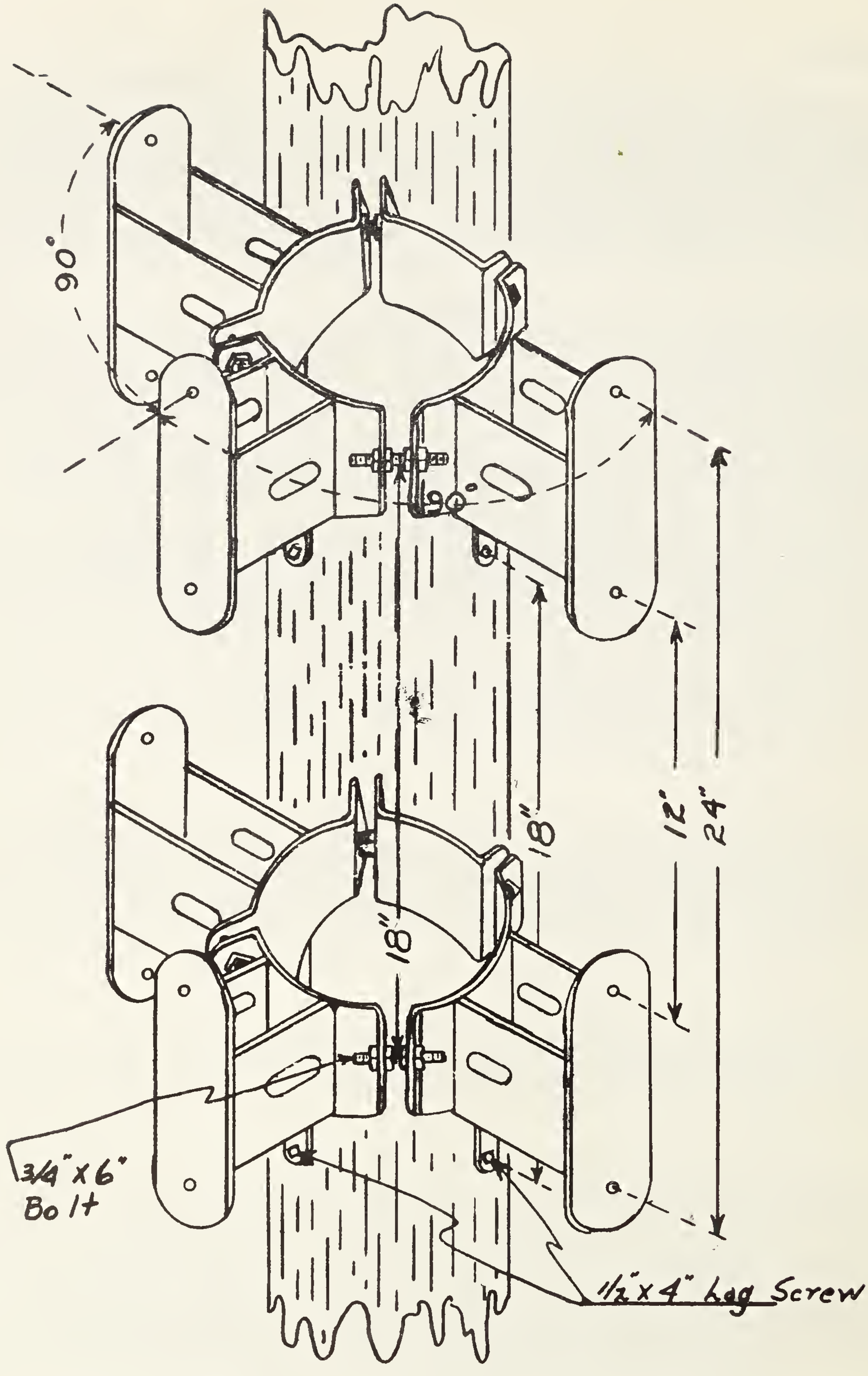


Fig. 1. Transformer mounting bracket

Fig. 2. Experimental installation of transformer mounting bracket

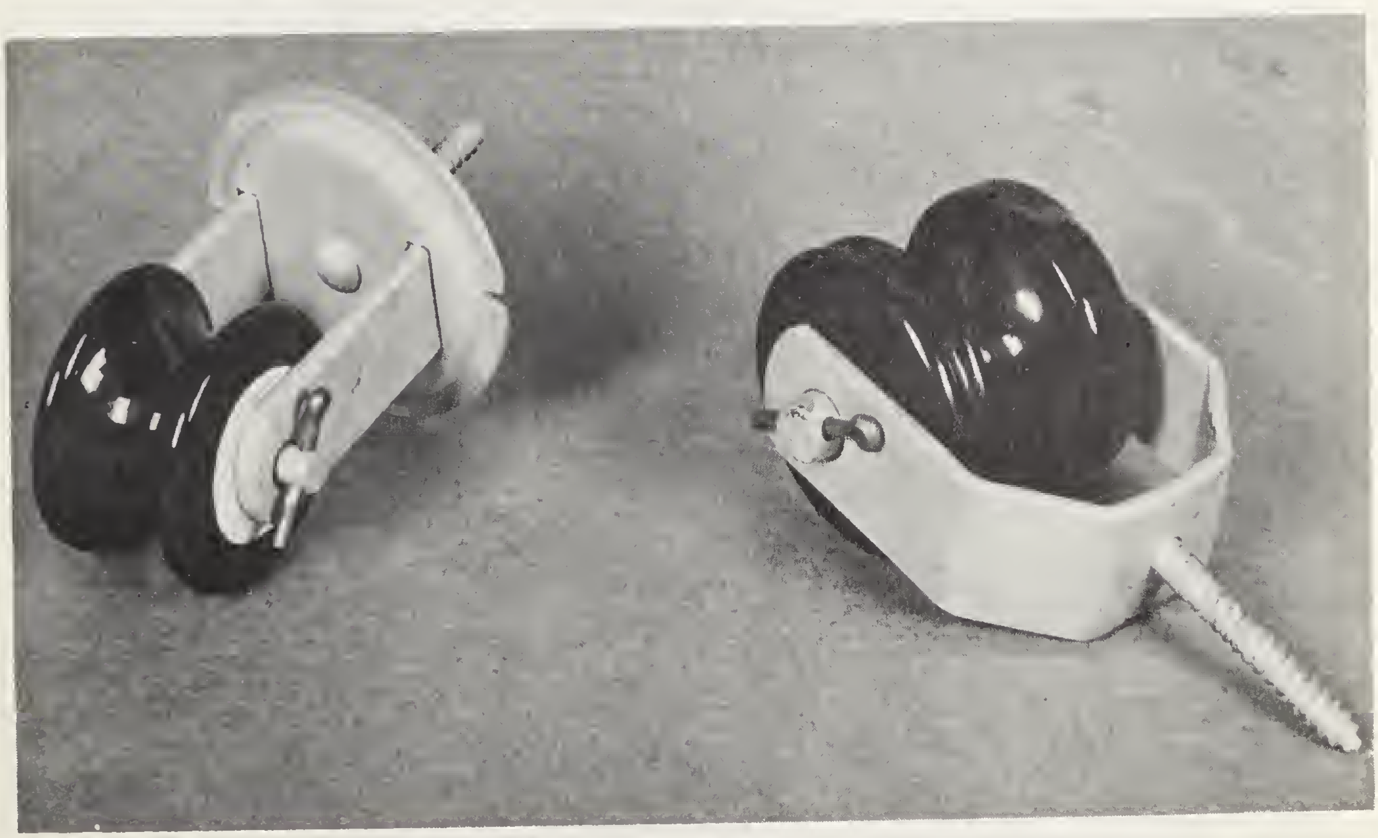


Fig. 3. Clevis type wireholders for service cable

Fig. 4. Service attachments for pipe mounting

Fig. 5. Preformed deadend for guys

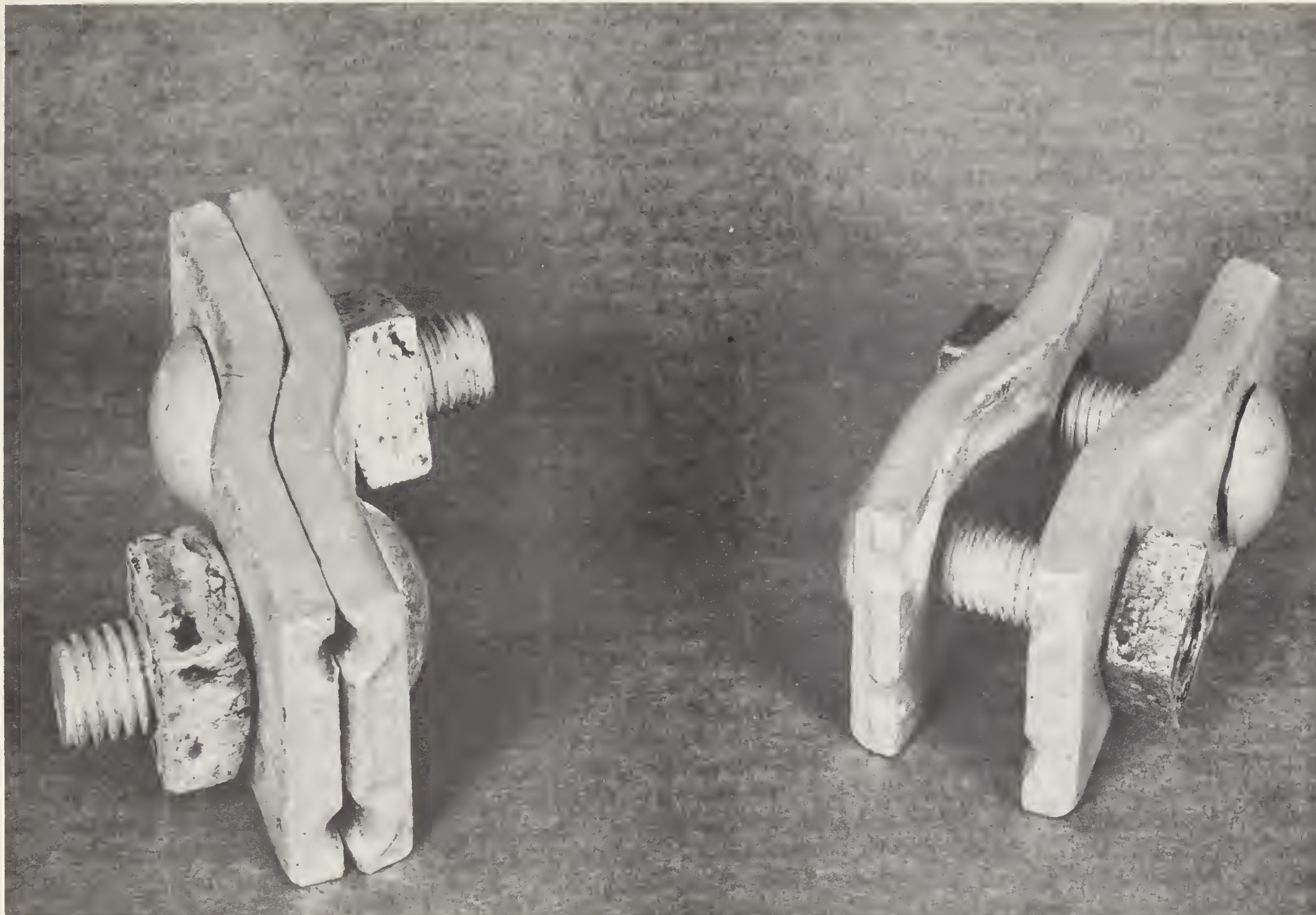


Fig. 6. Two-bolt guy clamps

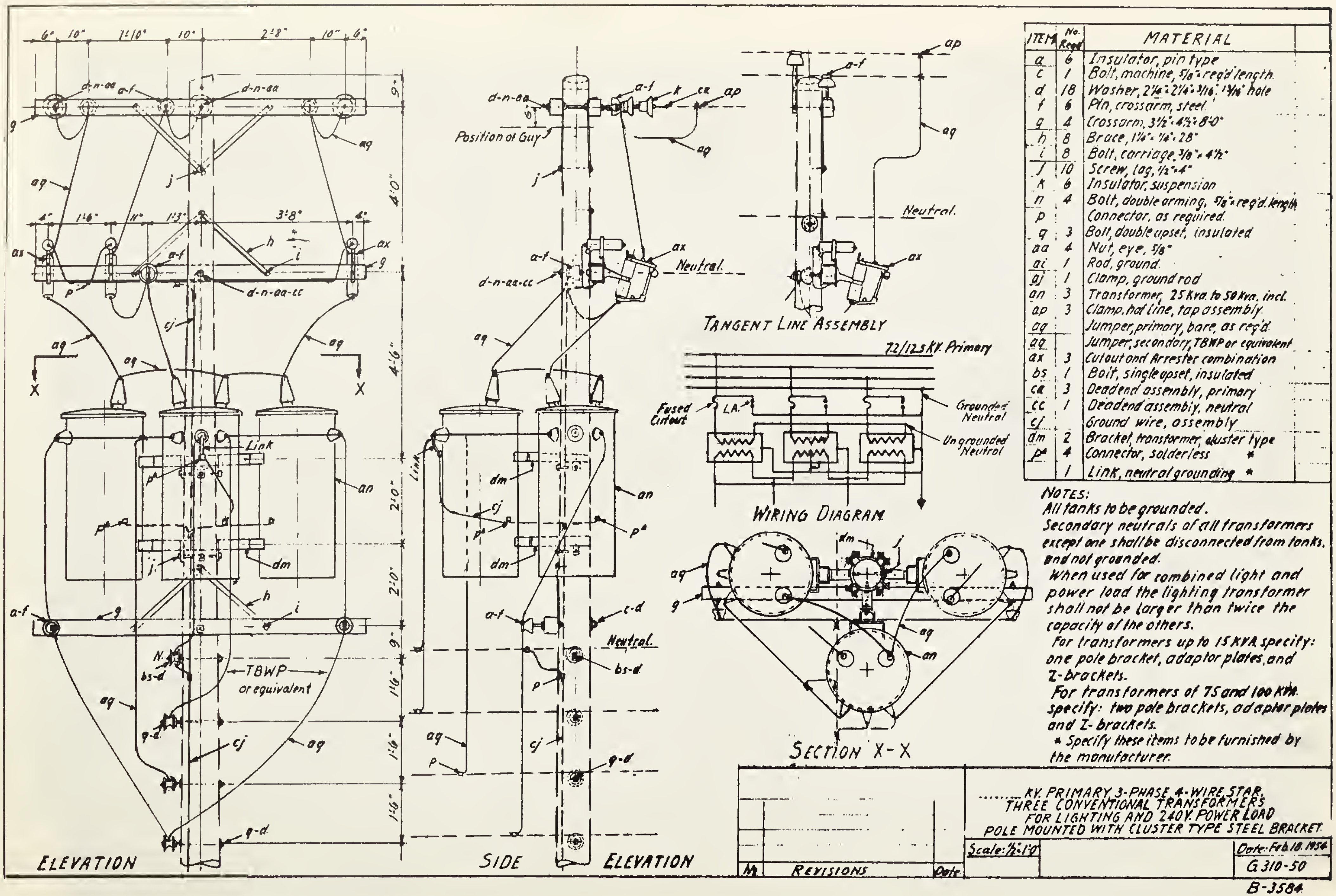
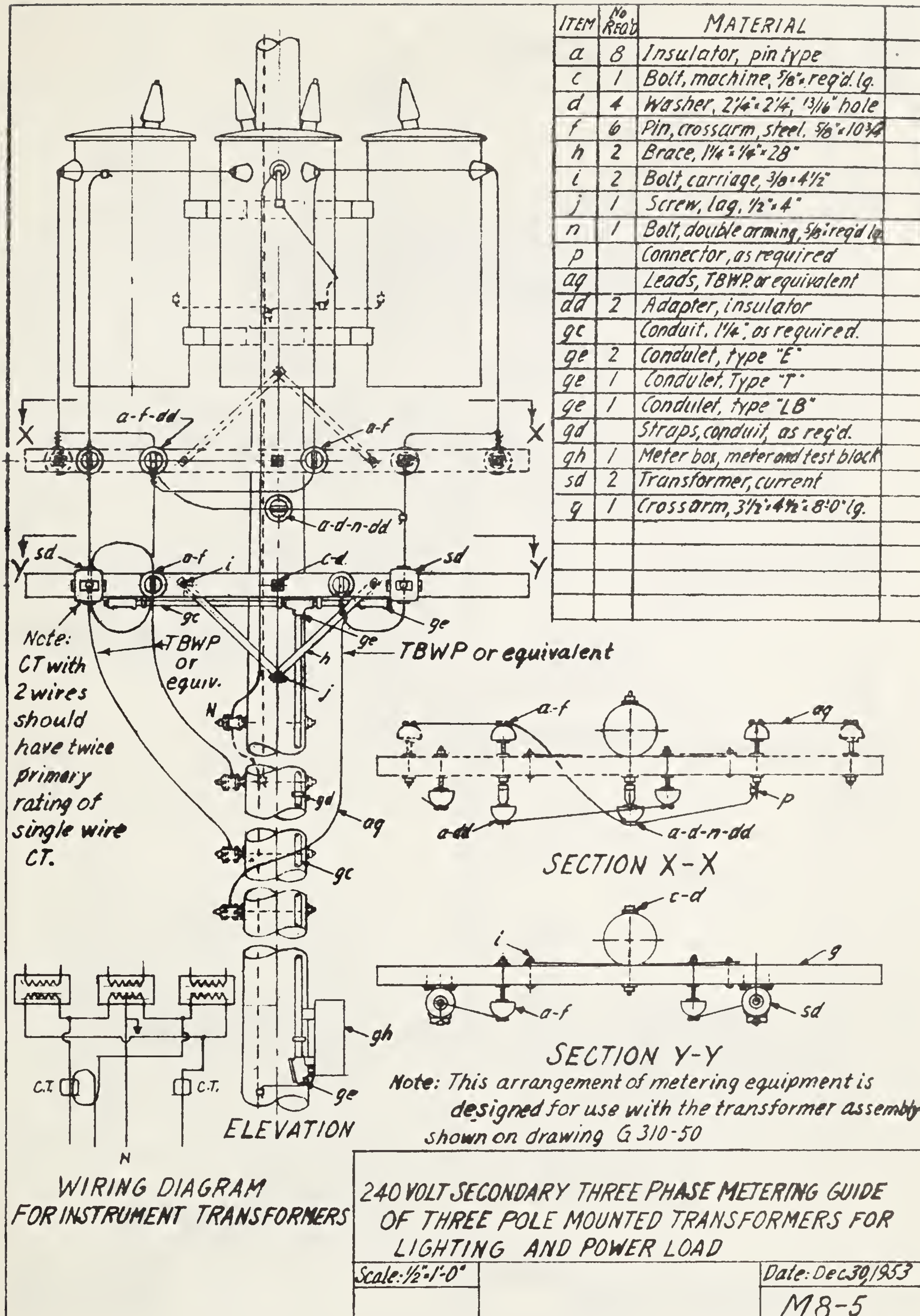
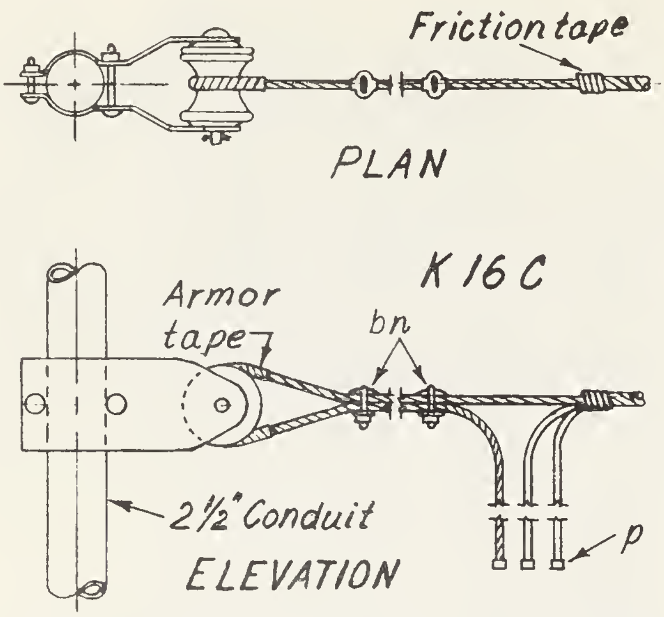


Fig. 7. Cluster mounting of three transformers

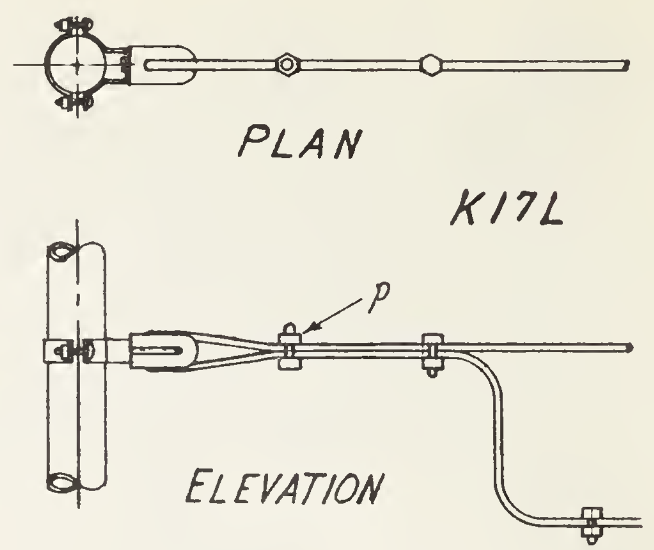


ITEM	No REQ'D	MATERIAL
a	8	Insulator, pin type
c	1	Bolt, machine, 5/8"× req'd. lg.
d	4	Washer, 2¼"×2¼", 13/16" hole
f	6	Pin, crossarm, steel, 5/8"×10¾"
h	2	Brace, 1¼"×¼"×28"
i	2	Bolt, carriage, 3/8"×4½"
j	1	Screw, lag, ½"×4"
n	1	Bolt, double arming, 5/8"× req'd lg.
p		Connector, as required
ag		Leads, TBWP or equivalent
dd	2	Adapter, insulator
gc		Conduit, 1¼", as required.
ge	2	Condulet, type "E"
ge	1	Condulet, Type "T"
ge	1	Condulet, type "LB"
gd		Straps, conduit, as req'd.
gh	1	Meter box, meter and test block
sd	2	Transformer, current
g	1	Crossarm, 3½"×4½"×8'0" lg.

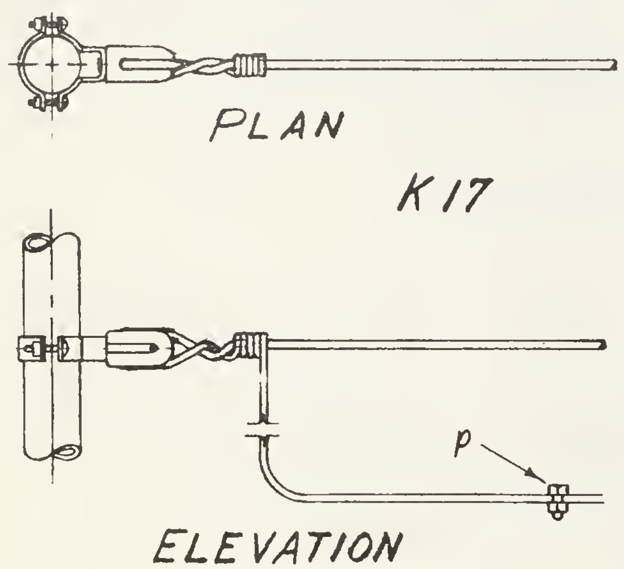
Fig. 8. Metering guide drawing for cluster transformer mounting



NOTE: This type construction should be used for three conductor service cables with bare ACSR neutral.



NOTE: This type construction should be used for No. 2 aluminum weatherproof conductor.



NOTES:

1. Connectors to be applied over bare wire and then taped as required.
2. For arrangement of service assembly units see drawing A-3580.

ITEM		MATERIAL		ITEM		MATERIAL	
p		Connectors, as required		bn		Clamp, loop deadend	
dr		Clevis, conduit insulated					
ds		Wireholder, conduit					

SERVICE ASSEMBLIES
(FOR RANCH TYPE HOUSES)

NO.	REVISION	DATE:	Scale: 1 1/2" = 1'-0"		Date: Sept. 30, 1953
					K16C, K17, K17L

Fig. 9. Service assemblies for ranch type houses

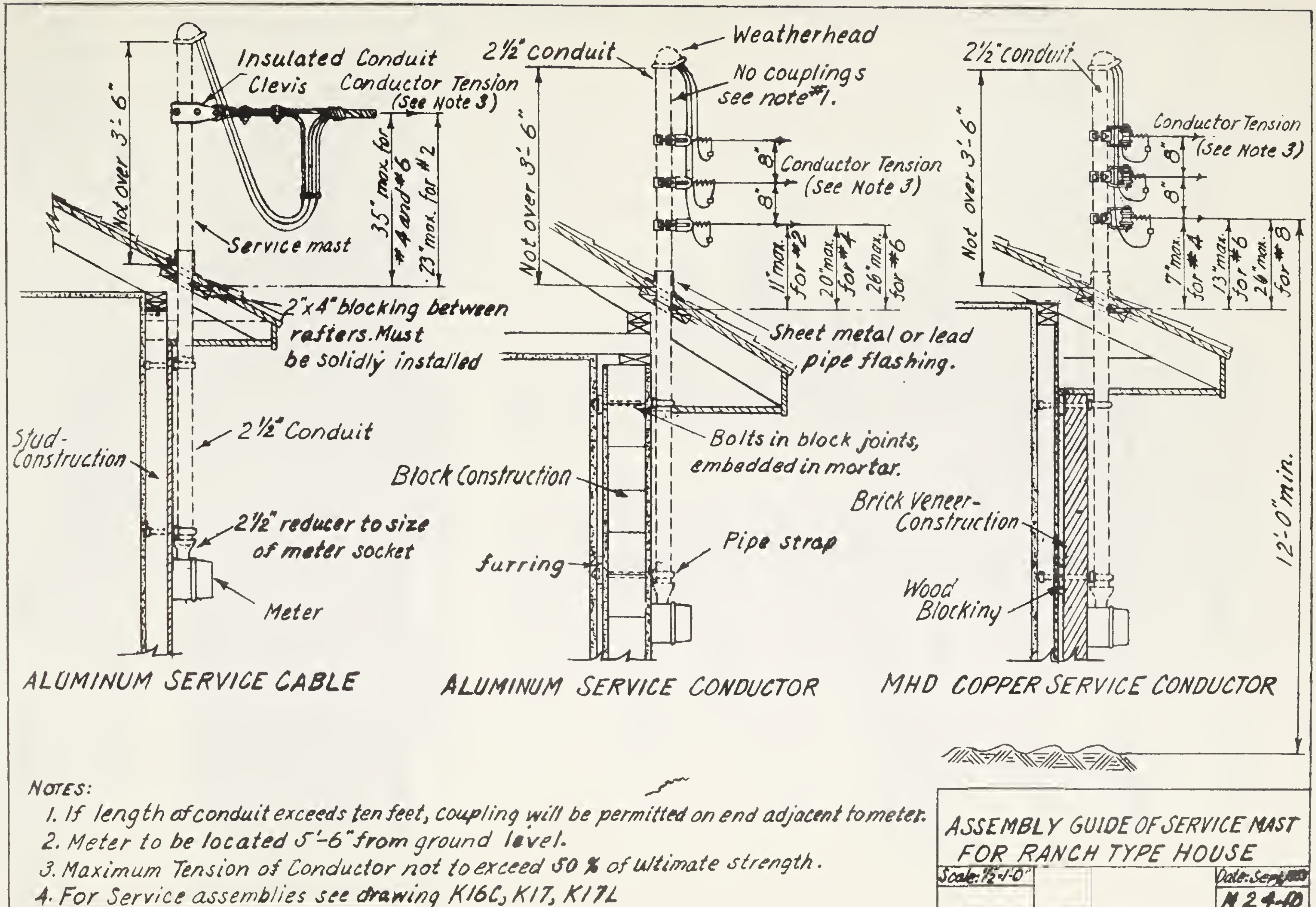
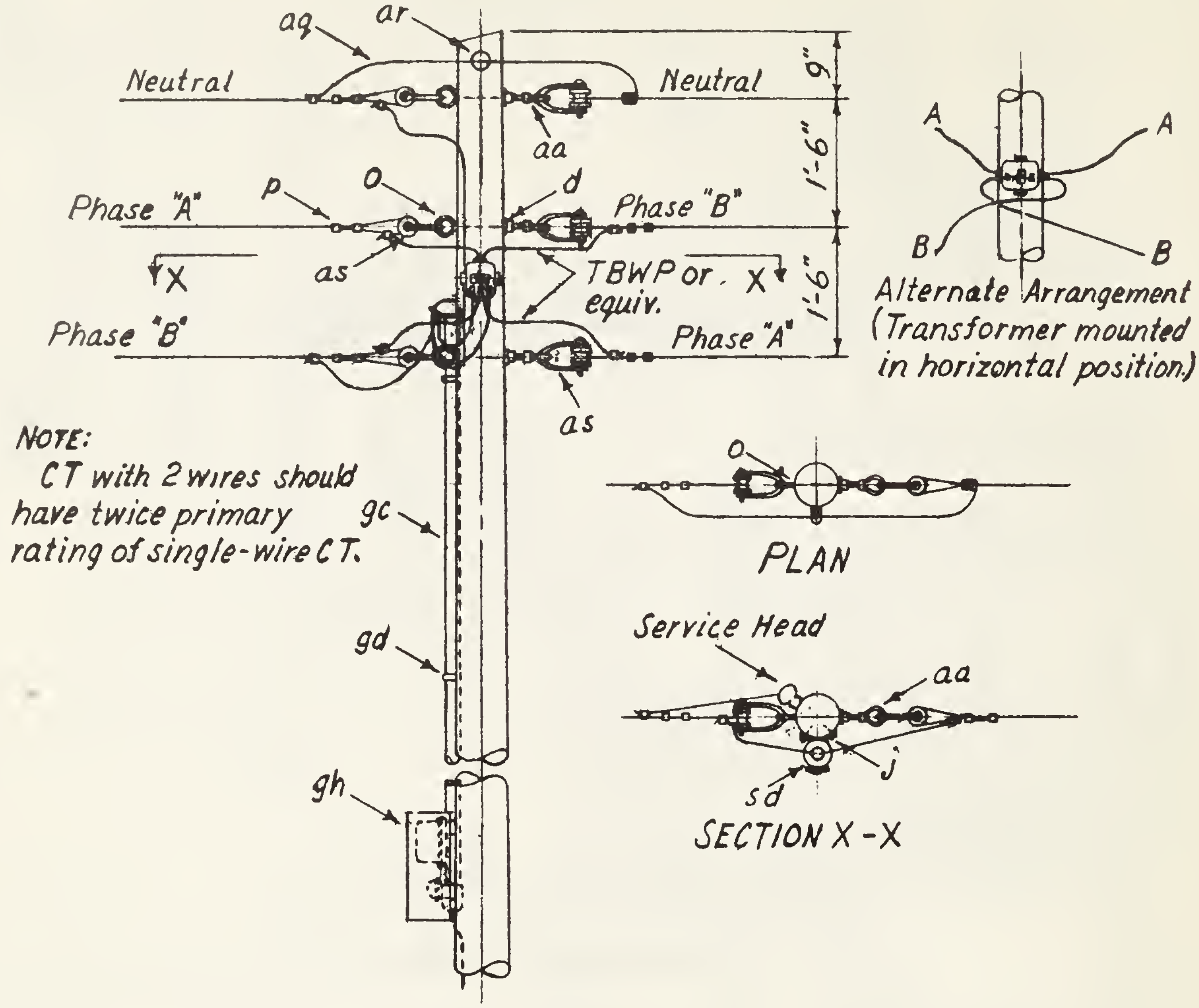


Fig. 10. Service mast and metering assembly guide



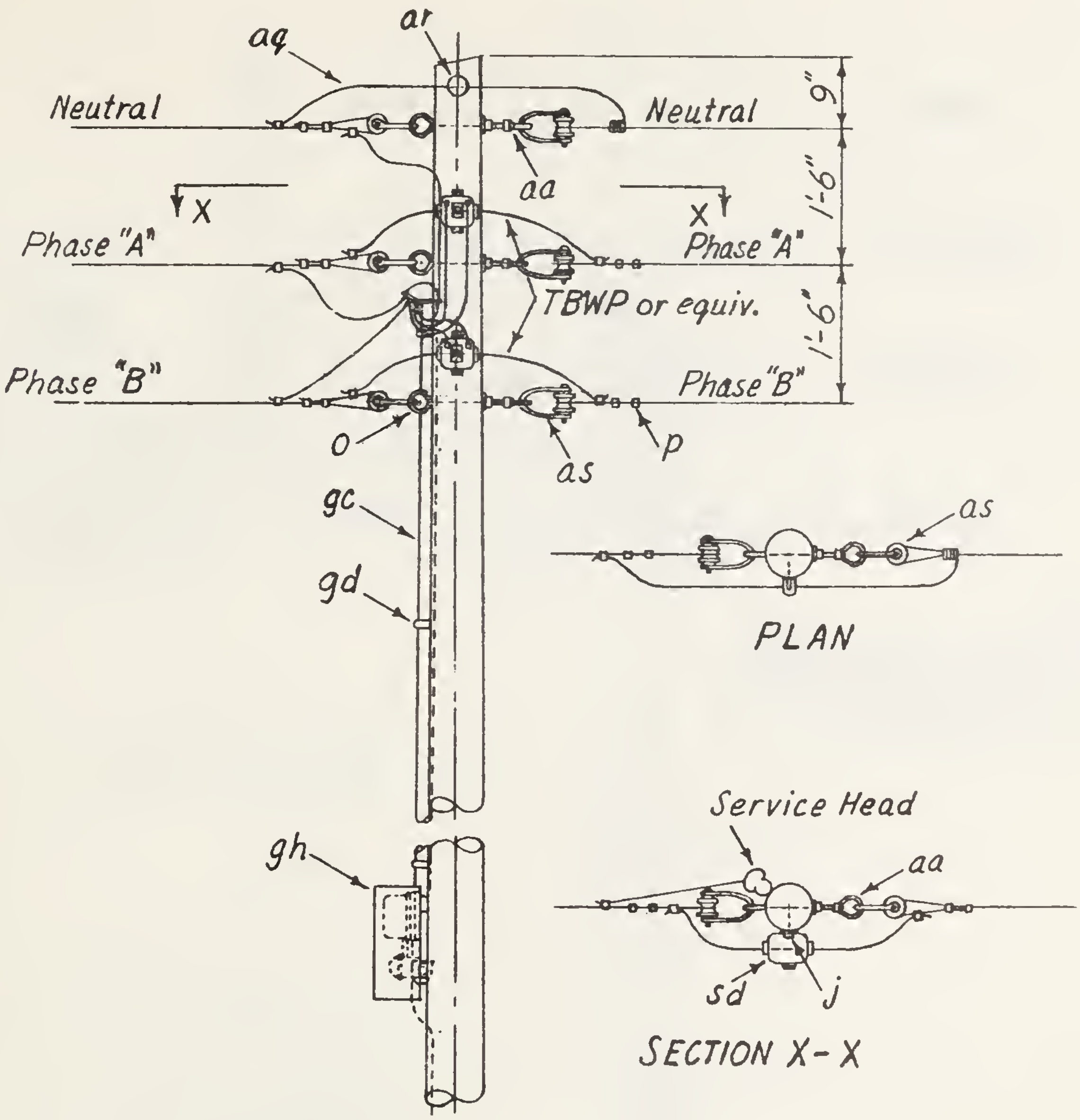
ITEM	NO. REQD	MATERIAL	ITEM	NO. REQD	MATERIAL
d	3	Washer, 2¼"x 2¼"x 3/16", 13/16" hole	gd		Straps, conduit, as required
j	2	Screw, lag	ge	1	Condulet, type LB
o	3	Bolt, eye, 5/8" x reqd. length		1	Service Head
p		Connectors, as required	gh	1	Meter box, meter and test block
aa	3	Nut, eye, 5/8"	sd	1	Transformer, current
aq		Jumpers, Insulated			Wire, No. 12 for current and
ar	1	Wireholder			No. 14 for potential
as	6	Clevis, service, swinging, insulated			
gc		Conduit, 1¼" as required			

SECONDARY METERING GUIDE
SINGLE PHASE 3-WIRE METERING 240 VOLTS

No.	REVISION	DATE:	Scale: ½"=1'-0"	Date: Sept. 15, 1954
				A-3589

M8-6

Fig. 11. Metering guide - single phase, 3-wire, 240 volts



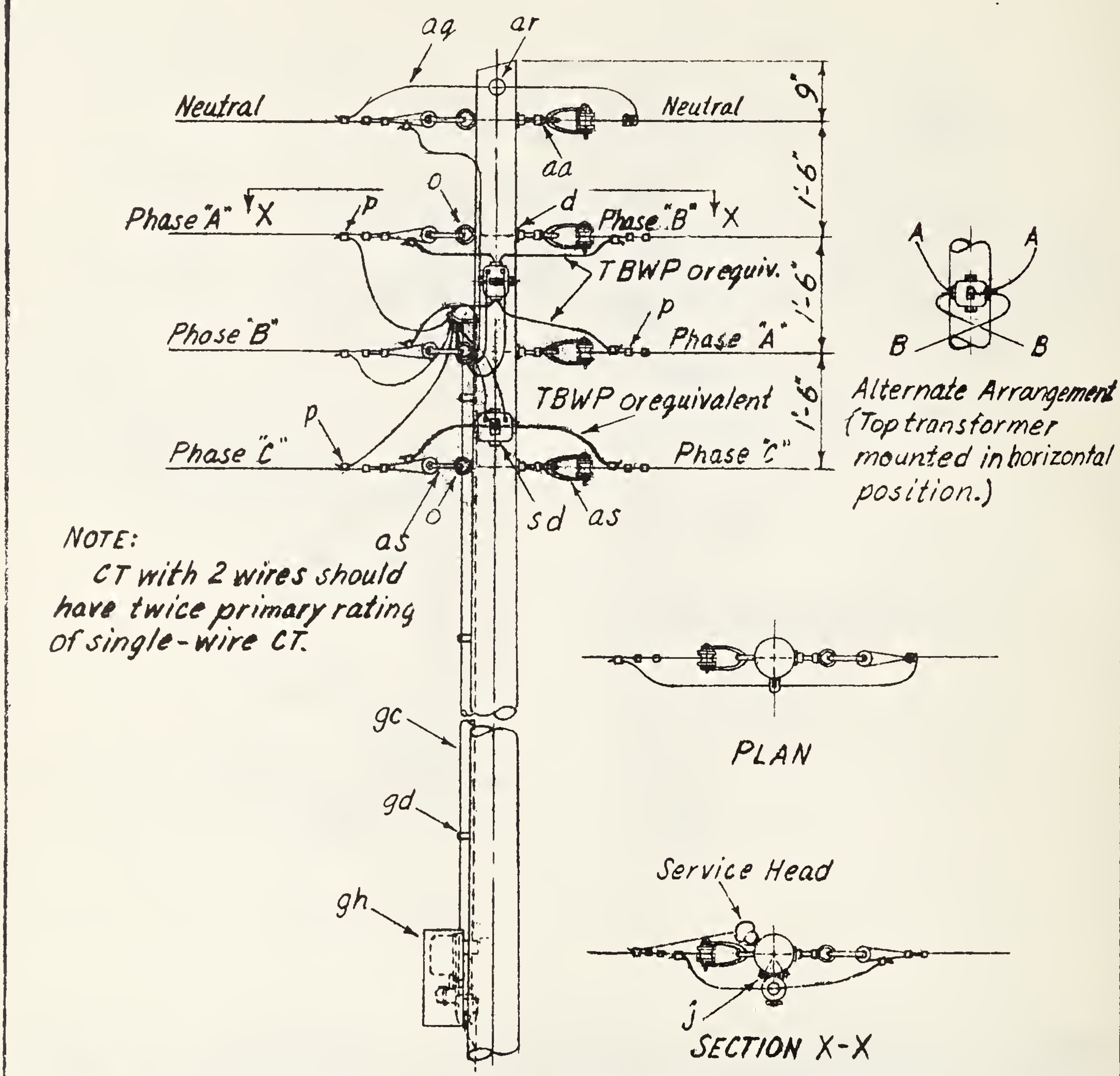
ITEM	NO. REQ'D	MATERIAL	ITEM	NO. REQ'D	MATERIAL
d	3	Washer, 2¼"x2¼"x 3/16", 13/16" hole	gd		Straps, conduit, as required
j	4	Screw, lag	ge	1	Condulet, type LB
o	3	Bolt, eye, 5/8" x req'd. length		1	Service Head
p		Connectors, as required	gh	1	Meter box, meter and test block
aa	3	Nut, eye, 5/8"	sd	2	Transformer, current
aq		Jumpers, Insulated			Wire, No. 12 for current and
ar	1	Wireholder			No. 14 for potential
as	6	Clevis, service, swinging, insulated			
gc		Conduit, 1¼" as required			

SECONDARY METERING GUIDE
THREE PHASE 3-WIRE METERING 240 VOLTS

No.	REVISION	DATE:	Scale: ½"=1'-0"	Date: Sept. 16, 1954
				A-3590

M8-7

Fig. 12. Metering guide - three phase, 3-wire, 240 volts



ITEM	NO. REQ'D	MATERIAL	ITEM	NO. REQ'D	MATERIAL
d	4	Washer, 2¼x2¼"x 3/16", 13/16" hole	as	8	Clevis, service, swinging, insulated
j	4	Screw, lag	gc		Conduit, 1¼" as required
o	4	Bolt, eye, 5/8" x req'd. length	gd		Straps, conduit, as required
p		Connectors, as req'd.	ge	1	Condulet, type "LB"
aa	4	Nut, eye, 5/8"		1	Service Head
ag		Jumpers, insulated	gh	1	Meter box, meter and test block
ar	1	Wireholder	sd	2	Transformer, Current
		Wire, No. 12 for current and			
		No. 14 for potential			

SECONDARY METERING GUIDE
THREE PHASE 4-WIRE Δ METERING 240 VOLTS

Scale: ½" = 1'-0"

Date: Sept. 15, 1954

A-3591

NO.	REVISION	DATE:

M8-8

Fig. 13. Metering guide - three phase, 4-wire, 240 volts

POLE INSPECTION AND MAINTENANCE

By C. H. Amadon, Consultant
Electric Engineering Division

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
January 17 - 21, 1955.

REA

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

POLE INSPECTION AND MAINTENANCE

C. H. Amadon

This paper and the oral presentation of it will be supplementary, and with the discussion which should follow, should add considerably to your own knowledge of poles and the problems they present in your service lines. It seems appropriate although the assigned topic is "Pole Inspection and Maintenance" that you should have something more than a casual acquaintance with poles and it is my purpose to present as briefly as I can the information about them that will be useful to you. Although poles in service are your principal concern, it may be desirable to go somewhat farther back than your acquisition of them and to lay a background on which to build up the information about poles in line and their maintenance. We shall cover in more or less detail the kinds of poles in common use, their characteristics, the preservatives and preservative treatments applicable to them. These are the background details. We shall then cover in somewhat more detail the hazards to which poles are subjected in line; methods of inspecting them for deterioration or damage; and remedial or preventive measures which can be taken to avoid loss in service and injury to the public and our own employees.

POLES

Species of Pole Timber

There are in general use throughout the country today nine species of pole timber from among the very considerable number of tree species in our native forests. The use of southern pine (5 distinct species) Douglas fir, western red cedar, western larch, and lodgepole pine reflects a choice influenced in part by availability and delivered cost in the roughly four geographical regions into which the United States may be divided.

Southern pine, although more widely distributed than any of the other kinds of poles is almost exclusively the one species used in the southeastern states; Douglas fir, originating in the Pacific Northwest, is used largely on the Pacific coast; western red cedar originating in Washington, Idaho and Montana is a favored species throughout the northern states and extensively used in the Pacific Northwest; western larch is a relatively recent (1945) addition to the list of accepted pole timbers, and is used in the same areas as western red cedar; lodgepole pine originates in the Rocky Mountains from central Colorado northward and is mostly used in its native region, although considerable numbers have been shipped eastward. Other species in minor usage are red (Norway) pine and jack pine in the Lake States region, and ponderosa pine in parts of California.

Rated Strength

Each of the pole species has been assigned a strength rating (modulus of rupture in static bending)based in all but two of the species on mechanical tests of pole size specimens. Those based on actual tests are --

southern pine rated at 7400 pounds per square inch,
lodgepole pine rated at 6600 pounds per square inch,
western red cedar rated at 5600 pounds per square inch,

The other species are —

western larch rated at 8400 pounds per square inch,
Douglas fir rated at 7400 pounds per square inch.

In the latter two cases the ratings were established by a committee sponsored by the American Standards Association; the rating for western larch was computed from the strength rating for small clear specimens of the wood as published by the Forest Products Laboratory at Madison, Wisconsin. The rating for Douglas fir poles was set at the same value as for southern pine on the basis of the generally accepted equal values for lumber and timber of the two species.

The validity of the assigned ratings has been questioned because of the nonuniformity of test methods and of the condition of the test specimens at time of the test, and the possibility that the timber itself is not now of the same quality as that which was previously tested and on which the present ratings were based. Some of the tests were made with the poles supported in a horizontal position in a rigid crib, with the load applied at a fixed distance from the top end. In this case, the poles were tested as cantilever beams, which they are in service unless guyed or braced. In other cases the poles were tested as simple beams, supported near each end, with the load applied near or at the distance from the butt end equal to the depth of setting for the pole under test. A further variant was in the moisture content of the poles at time of test; some were essentially "green" or unseasoned; in others, the moisture content was at or below the fiber saturation point and in a condition with respect to moisture at which further reduction in moisture content of the wood results in an increase in strength. There seemed to be no principle by which the strength values derived from different methods of test and from tests of poles in different states of seasoning could be reconciled. There has been no evidence however that the strength of the poles has been over rated. Nevertheless, there is now in progress at the Forest Products Laboratory a series of new tests sponsored by the American Society for Testing Materials. These tests are designed to eliminate the two principal objections to the previous tests and as nearly as possible to duplicate all of the controllable details of test for each specimen of each of the five kinds of pole timber.

Standard Dimensions of Poles

Under the sponsorship of the American Standards Association another subcommittee established dimensional standards for poles of each species in seven classes (1 to 7) in lengths up to the maximum of available poles for these, the limiting dimensions (circumference) applies at the top and at six feet from the butt end; in addition, three classes (8, 9 and 10) were classified on the basis of top circumference only. The dimensions at six feet from the butt were set at such values, using the standard fiber strength ratings that all poles in a given class would hold the same load regardless of the species of timber; in like manner all poles of a given class would hold the same load regardless of length. Poles in Class 7 are designed to sustain a load of twelve hundred pounds applied at two feet from the top; poles in each larger class are designed to sustain a 25 percent greater load than the next smaller pole.

Specifications for Poles

Still another committee of the American Standards Association established standards for quality of acceptable poles, placing limits on, or prohibiting certain strength reducing features, on deviation from straightness, on manufacturing (bark removal, trimming and thelike). These specifications have had general acceptance throughout the country, and have been modified by some pole using interests only as their own needs indicated.

Durability of Poles

These five kinds of pole timber fall naturally into three groups based on natural durability or resistance to fungus attack (decay); western red cedar and western larch have a notably durable heartwood encased in a relatively thin non-durable sapwood ranging in thickness from 0.5 inch to 1.25 inches; Douglas fir and southern pine have a fairly durable heartwood encased in a non-durable sapwood of from 0.7 inch to 2 inches in Douglas and from 1.25 inches to as much as 4 inches in southern pine; in lodgepole pine the non-durable heartwood is encased in non-durable sapwood ranging in thickness from about 0.5 inch to 2.5 inches in thickness.

Because the sapwood of all species of pole timber is not resistant to decay, infection of untreated sapwood in contact with the soil is certain except in very wet or very dry locations. Experience has shown that the thin sapwood in the ground section of western red cedar and western larch will be practically destroyed by decay within the first five years; in lodgepole pine the period may be from five to seven years; in Douglas fir and southern pine from seven to ten years. Thus in an untreated pole or one in which the preservative was not effective having average sapwood thickness for its species and a 30-inch circumference at the ground line when placed, the loss of the sapwood results in less in strength about as follows:

Western red cedar	40% in about 5 years
Lodgepole pine	70% in about 7 years
Douglas fir	77% in about 10 years
Southern pine	total failure in about 10 years.

In lodgepole pine however the loss in strength may continue at an undiminished rate because of non-durability of the heartwood, so that total failure may occur in about 10 years or sooner.

Penetrability of the Wood by Preservatives

The heartwood of all species of pole timber is highly resistant to penetration by any of the commonly used standard wood-preservatives using present treating plant equipment and methods. However, when properly conditioned the sapwood can be satisfactorily impregnated with these preservatives resulting in a high degree of resistance to destruction by fungi and wood-eating insects.

Conditioning of the wood involves generally the removal of a considerable quantity of the sapwood water which is present in the wood cells comprising the sapwood. The poles may be naturally conditioned by exposure to the air in seasoning stacks. Where this can be done without risk of fungus infection and decay, as in regions

of relatively low atmospheric humidity, air-seasoning is to be preferred over all other methods. The slow loss of moisture during air-seasoning is desirably accompanied by shrinkage which results in the development of checks or lengthwise openings extending from the surface toward the center of the pole. When these checks, occur before the poles are subjected to the treating process, the preservative during treatment enters to the full depth of them thus preventing the later exposure of untreated wood which could result when deep checks develop after treatment of unseasoned poles. Air-seasoning is highly essential in the case of lodgepole pine, because of its non-durable heartwood; air-seasoning is to be preferred for western larch and western red cedar to facilitate penetration of the sapwood by non-pressure process. Air-seasoning is not wholly practicable for conditioning Douglas fir and southern pine largely because the local or regional atmospheric conditions are unfavorable. These timbers are artifically conditioned just prior to unpregnation, by heating in the preservative under a vacuum (Douglas fir) or by steam and vacuum (southern pine).

PRESERVATIVES

At the outset of the wood-preserving industry coal tar creosote was used almost exclusively, although there was a relatively small output of materials treated with toxic salts like copper-sulphate, zinc chloride and the like in water solutions. Creosote originally was imported from England, later from continental Europe, still later from Japan. Meantime the domestic production of creosote was stepped up to keep pace with the expanding demand for preserved poles, ties and structural timbers.

Creosote was not acceptable as a wood-preservative for universal use. Creosoted timber could not be successfully painted; the odor of it was considered objectionable, or prevented its use where commodities could be contaminated as to odor or taste. Moreover, the improved art of coal tar distillation resulted in the recovery of many by-products having greater commercial value, than as components of creosote. This had the effect of rendering coal tar creosote a variable commodity, having at times, undesirable characteristics as well as unknown effectiveness as a wood-preservative. New preservatives were introduced from time to time; water borne salts have not been accepted generally; oil borne preservatives such as copper naphthenate and pentachlorophenol appear to be the most acceptable but at present only pentachlorophenol in solution in petroleum (5% by weight) is in extensive use. This preservative solution is considered the equivalent in toxic property with the kind of creosote which has given long time protection to wood; it is used wherever creosote has been used (except for marine piling and railroad ties) and for many purposes creosote is objectionable.

There have been periods of increased demand for poles accompanied by a shortage of creosote. Such a period occurred during 1946 to mid 1948. When there was a tremendous backlog of demand for poles as the war ended; there was a concurrent critical shortage of creosote because of the complete stoppage of importations. As a result, solutions of creosote with petroleum, and with refined tar, had to be used; by-products of the production of illuminating and cooking gas, and distillates from admixtures of coal tar and water gas tar were offered and used to some extent; penta solutions were accepted but a shortage of penta developed during 1947. During this period, many thousands of poles were treated and placed in service, in which insufficient quantities of a substandard preservative were used. The results are now becoming evident in the complete deterioration in the section below ground of an increasing number of poles in line.

METHODS OF PRESERVATIVE TREATMENT

Two standard methods of impregnating wood with preservatives are in common use; a method by which the preservative is forced under pressure into the timber, and a method by which the wood simply absorbs the preservative under none but atmospheric pressure.

Pressure Processes

In current pressure-treating practice, poles may be impregnated by the full-cell, or Bethell process or by the empty-cell or Rueping process. The full-cell process is generally specified where deep penetration and a heavy concentration of preservative are desired, as for marine structures, or in tropic climates where exposure to fungi and insects is severe. The empty-cell process is generally specified where deep penetration is desired but where lighter concentrations of preservative are adequate for the conditions of exposure. In the first or full-cell process the specified quantity of preservative is pressed into the timber and the treating process is terminated; in the second or empty-cell process an excess of preservative is pressed into the timber, and recovered by the combined effect of two stages in the process which are not a part of the full-cell process. These two stages are, a period of air pressure in excess of atmospheric pressure before the impregnation period and a vacuum following the impregnation period and after the unused preservative has been withdrawn from the cylinder.

Non-Pressure Processes

The non-pressure process is simply the submersion of the poles in the preservative, where treatment full length is desired, or immersion of the butts of the poles where butt treatment only is desired. The first stage of this treatment is in hot preservative (about 230°F.) for from 6 to 10 hours; this is followed usually by quick removal of the hot oil and introduction of cool preservative (usually at about 100°F.) duration of this phase is from two to four hours. aIn some cases the hot preservative is not withdrawn but is simply allowed to remain until its temperature has dropped to 150°F. The hot period tends to expel air and moisture from the sapwood cells, thus facilitating absorption of the preservative during the cooling or cold oil period.

The non-pressure process is not generally used with pole timbers having deep sapwood; it is most commonly used in treating western red cedar and western larch.

RESULTS OF TREATMENT

Results of treatment by pressure processes are customarily defined in terms of retention and of penetration by the preservative. The required quantity of preservative is generally defined in terms of pounds per cubic foot of total volume of the pole, and is determined by means of calibrated measuring devices. Less frequently, the retention may be determined by extraction of the preservative from representative samples of the treated wood and relating that quantity to the volume of wood in the sample. The retention in poles treated by non-pressure process in open tanks cannot be accurately determined by gauges, and is not generally specified. The criterion for acceptance of these poles is the depth of penetration of the preservative, expressed in inches of depth from the surface (of the pole) and as a percent of the sapwood thickness. Penetration is measured on slim cores taken with a special tool from each of a specified number of poles in any lot offered for acceptance. Thus, for southern pine, treated

to an 8 pound retention, the required penetration is 2.5 inches unless the penetration is also 85 percent of the sapwood thickness; in western red cedar the acceptable penetration is not less than 0.5 inch unless it also is 100 percent of the sapwood thickness.

Specifications

Standard specifications such as those issued by the American Standards Association may be adopted in entirety by producers and users of the covered commodities, or modified by a user to meet his specific needs. Thus, REA has adopted the standard pole specifications issued by the American Standards Association with a few changes and additions; the specifications for preservatives and for treatment are based on specifications approved by the American Wood Preservers' Association. Adherence to these REA specifications in the selection, manufacture and treatment with approved preservatives can be expected to result in high grade poles having the desired life in service.

Experience has shown however that departures from the standards usually results in a sub-standard article having a doubtful service life. Some of the departures from standard may have been authorized after consideration of the temporary emergencies and shortage of supply; some departures have been the result of carelessness or inefficiency on the part of producer or inspector. The results are now becoming apparent in the early failure of a considerable number of poles in service; this indicates the need for two specific activities in which the cooperatives have a primary interest and one in which the field engineer and the cooperative have a joint and primary interest. The first one relates to sub-standard poles already in use; it involves consideration of the problems posed by the substandard poles; prompt development of plans to inspect where there is reason to believe, or evidence to show, that the poles are already seriously deteriorated; and initiation of a repair or replacement program . The second activity involves specific plans for inspection of new poles at time of delivery, and prompt reporting in detail of any non-specification quality so that appropriate action can be taken promptly.

INSPECTION OF POLES IN LINE

Inspection of poles in line is nothing more nor less than an examination in sufficient detail to determine the present condition of each individual pole. Based on the conditions revealed by this inspection, an appraisal or estimate of the remaining service life can be made with a fair degree of accuracy. Such an inspection and appraisal with appropriate action based on them can prevent a large part of the economic wasteresulting from too early removal of poles from line, and the menace to property and life, and disruption of service, which may result from failure of a pole.

It should not be assumed that inspection and appraisal of poles can be based on a set of hard and fast rules of procedure and on strict mathematical formulae. Rather it should be understood that inspection should follow a general routine and a general formulae and that interpretation of the results must be made with judgment based on experience.

However, a working knowledge of the agencies (other than aging) which affect the strength and stability of a pole in service is helpful to those engaged in inspection and evaluation of the remaining service life at any inspection date.

Deterioration and Damage to Poles in Line

The destructive agents to which poles in line are exposed may be grouped in two categories. In one group are wood-destroying insects and fungi which consume wood substance very slowly. In the other group are storm, fire, and collision which may weaken or suddenly render the pole useless, and woodpeckers which if very active may quickly do considerable damage to individual poles. Destruction by fungi and insects may well be referred to as deterioration to distinguish it, for purposes of discussion, from the effect of fire, storm, collision and woodpeckers referred to as damage.

Deterioration may actually begin in the ground section within the first year after the setting of an untreated cedar pole and it may progress rapidly during the first few years in the non-durable sapwood, but more slowly threafter in the decay-resistant heartwood. In the case of properly treated poles of all species, deterioration of the treated wood is almost imperceptible even over a long period of years. Thick sapwood poles, if not deeply impregnated, may show early decay in the untreated inner sapwood portion, resulting eventually in loss of enough sound wood to render the pole useless.

Damage may take place almost immediately, or may be deferred for many years, or may never happen. In any case damage becomes evident as soon as it happens and may be dealt with as soon as practicable. Of itself, damage may not be sufficiently extensive to warrant removal of the pole, but it may produce openings through which fungi and insects may enter and begin their slow deterioration of the pole.

Wood-Destroying Fungi

It is not the intention hereto discuss these destructive agents at great length, but instead to point out some of the important factors about them as a group and some of the specifically important facts about those which are commonly found in poles.

Wood-destroying fungi infect wood in two ways. Spores or "seeds" of the fungus are produced in enormous numbers and are carried by birds and insects or blown about very widely, finding lodgement on practically everything on or above the ground. A conspicuous example of spore production is the common puff-ball frequently to be found in fields and pastures. The cloud of "smoke" which arises when a ripe puff-ball is crushed is composed of millions of spores. Spores of wood destroying fungi which are deposited on wood in favorably moist condition for their development, almost immediately begin to grow in much the same fashion that planted seeds grow. Or, the fungus itself may be present in the soil into which a pole is set, in which case if the pole is untreated, it may become infected almost immediately. Once the fungus, whether from spores or from the plant itself, becomes well established in a pole it will continue to grow as long as conditions are favorable.

Moisture and air are necessary to the life of the fungus, and if either is lacking or restricted, the growth of the fungus is prevented or inhibited. Wood that is thoroughly and constantly wet does not rot because air is lacking. Wood that is thoroughly and constantly dry does not rot because moisture is lacking. An untreated pole set in a swamp usually decays just above the ground or water line, because air is lacking below that line; such a pole set in deep loose sand or gravel usually decays from a few inches below the ground line downward because sufficient moisture is lacking above that line. In most soils however, the region of greatest decay is from just above the ground line to 10 to 15 inches below that line.

Wood-Destroying Insects

Carpenter ants, the large black, and the black and red species, should be considered as major destructive agents of cedar poles, and care should be taken to detect their presence. These ants seem to be especially attracted to poles with internal decay or cavities, which they enter and enlarge for nesting purposes. The points of entry are usually close to the ground line although some cases have been observed where the points of entry and location of greatest damage were several feet above ground. Even a few ants noticed in excavating around a pole for inspection purposes may be an indication that the pole is infested. Woodpecker holes in a pole are frequently to be taken as an indication that the pole is infested with ants. Tapping the pole to detect internal unsoundness may arouse the colony and cause many of the ants to appear for investigation of the disturbance. Carpenter ants do not eat the wood; they remove it in fine sawdust-like particles which they carry to the outside of the pole. If their principal workings are above the ground line this fine wood dust accumulation is usually very noticeable and is a sure indication that ants are or have been at work in the pole. Since their workings are primarily used as chambers in which their eggs are deposited and their young larvae are fed, carpenter ants are unlikely to leave a pole unless frequently disturbed or unless the nest is made unhabitable or objectionable to them. Wood preservatives injected into the nest through holes bored for the purpose have been found notably effective in destroying a colony or causing the ants to leave the pole.

Termites are soft grayish-white insects commonly but erroneously called "white ants". Because of their widespread distribution throughout the United States and because cellulose is their principle article of food these insects are of interest as potential destroyers of untreated poles and other wood in structures in the electric and telephone plant.

In general termites are classified as (a) subterranean termites, (b) damp-wood termites and (c) dry wood (aerial) termites. Termites of the first group are found in practically all parts of the country; those of the second group are found in the Pacific Coast States and are notably prevalent in California; those of the third group have been found only along the coast from Virginia to Florida and Texas and along the Mexican border to California.

Subterranean and damp-wood termites have much the same life habits. Both varieties inhabit the soil or wood in contact with the soil and require considerable moisture. Subterranean termites if present, will usually be found in outer decaying wood from the groundline downward; damp-wood termites may be found in poles just above and not far from the ground line. Dry-wood termites, as the name implies, do not need moisture, and seem to prefer dry conditions. They are found in poles only in the aerial section or sometimes in crossarms and insulator pins.

Termites appear voluntarily in the open air only during the swarming season, when large numbers of adult males and females leave the home nest. These flying termites, during this flight season have black bodies and pearl-gray wings which are considerably longer than their bodies. In california the flight season for the subterranean type is in the autumn on sunny days after the seasonal rains begin, whereas the majority of the damp-wood termites swarm at any time between July and November when warm, sultry atmospheric conditions prevail. Elsewhere subterranean termites swarm in spring and autumn.

Their ability to fly is limited and unless blown to greater distances their flight usually ends within about 100 yards. At the end of their flight termites cast their wings, seek a mate and together seek out and prepare a new home. The subterranean species usually enter the ground or some suitable location like an old stump or log or a pole in contact with the soil; the damp-wood species rarely enter the ground but are attracted to some decaying piece of wood which they enter at a point above but close to the ground. Unquestionably very few mated pairs survive the swarming flight and the hazards of preparing a new home. Those which succeed however begin at once the establishment of a new colony, the increase of which is very slow for the first two years. By the end of four years or more under favorable circumstances the colony may have increased sufficiently to produce a new swarm.

The history of the swarming flight, mating and establishment of new colonies of dry-wood termites is much the same as for the other types, except that the mated pair enter some wooden structure above the ground, seal themselves in and never leave the nest. They reproduce very slowly but are rarely found until their damage has been extensive.

Although termites are capable of consuming sound wood, the damp-wood type and the subterranean type apparently prefer wood which has already been attacked by a wood destroying fungus provided however that the fungus is not a cellulose destroyer. This apparent preference is because cellulose is the only part of the wood substance which termites can digest. These two types of termites can usually be controlled by the same measures applied against fungus attack. The dry-wood termites attack in the dry portions of a pole and because they may remain undiscovered until extensive damage reveals their presence, remedial measures are of little practical use. For this reason only full length treated poles should be used when dry-wood termites are likely to be found.

Fire, Lightning, Collision, Woodpeckers

The extent of damage by fire, lightning and collision can be readily observed and appraised on the basis of judgment and application of the general rules relating to pole inspection.

In the case of a fire damaged pole it should be possible to reach a reasonably sound conclusion as to the existing damage and whether or not the fires are likely to be recurrent, as for example, grass fires, or weed burning by highway maintenance forces. In such case new damage during the next inspection period might well be of sufficient extent to weaken the pole seriously.

Lightning damage may be superficial or may shatter the pole badly; appraisal of the damage is purely a matter of judgment. Some pole positions are struck repeatedly; consideration should therefore be given to a recommendation for installation of lightning protection.

Damage by collision should also be appraised according to the inspector's best judgment. The recommendation, in case of need for replacement, should include relocation if it appears that the present location of itself contributes to the collision hazard.

Woodpecker damage is largely mechanical and should not invariably be considered a cause for condemnation; the attacked pole should be carefully inspected for associated

decay or other damage and appraised accordingly. In some cases woodpecker attack is associated with internal decay or insect infestation; the pole should therefore be appraised primarily on the basis of decay and insect damage. In other cases the attack is associated with a "ring shake" which is a separation between growth rings and rarely affects the strength of a pole sufficiently to warrant replacement. A large hole, one of sufficient size, to admit the bird itself, usually indicates a nexting cavity; in such case the pole may be seriously weakened at the location of the hole.

Other Reasons for Removal or Replacement

Removal or replacement of poles for reasons other than deterioration or damage may be necessary in some cases. Poles may be of insufficient height, where for example, recently added or proposed additions to service attachments do not allow sufficient clearance between the ground and the attachments, either at the pole or between poles, or between trees where trimming rights cannot be obtained, or where farm lanes or field entrances made since the building of the line require higher poles to provide for safe passage of farm equipment.

Some poles may be in locations creating a possible public hazard, as for example, where road improvement has brought the traffic lane too close to the pole. This hazard may be particularly serious in the case of poles on the outer side of a curve in a high crowned road or on a down grade where speed or road surface conditions may tend to throw vehicles off the roadway. In some cases road grading may have lowered the ground line of a pole sufficiently to make it unstable; such poles may be reset, if long enough, or a guy may be installed, or if neither of these alternatives is practicable the pole should be replaced. Some poles may be removed and not be replaced in lines where a program of respacing is involved.

In still other cases involving several poles consideration should be given to the section as a whole. By way of illustration, assume that, in a section of five poles, the first and fifth poles are recent replacements. The middle pole should unquestionably be replaced, and the other two are "questionable" or "borderline" poles. If the middle pole is replaced the other two deteriorating poles will each be backed up by good poles, and probably adding several years to the life of the intermediate poles. On the other hand, there might be real economy in the long run if all three poles were replaced at one time. It is clear, of course, that the economies of line maintenance, work load in any year, joint use and other management considerations will have a strong bearing on the decision. The inspector's recommendation in such cases should be subject to review by other interested departments.

Inspector's Equipment

The tools and implements comprising the inspector's equipment will be largely indicated by the kind of poles to be inspected, the nature of the ground and the means of transportation available. The essential tools are a "sounding" implement (such as a hatchet), an increment borer, a prod, 6-foot tape, replacement-circumference charts and wire conversion table, and, if excavating around the poles is anticipated, some convenient type of round-pointed spade or shovel. A light bar or pick may be useful for digging in hard, tight, or rocky soil.

The preferred "sounding" tool is a light ($1\frac{1}{4}$ pound) short handled hatchet. The increment borer is a standard tool designed to remove a slim core of wood from a pole

under examination. The wire conversion and replacement-circumference charts are given in REA Bulletin No. 161-4 T O & M Series entitled "Pole Inspection and Maintenance". The other tools and implements are usually and, in many cases, preferably obtained locally.

The remainder of the inspection equipment should include the necessary forms for the current inspection data, pencils, plugs for filling borer holes, etc., together with the record of next preceding inspection if any is available.

Inspection Records

Properly kept records provide the best basis for estimating the expected performance of a pole. Thus, a record of the circumference of good wood at or below the ground line of untreated poles together with dimensions of exposed or enclosed decay pockets and notation as to insect infestation will enable the inspector at any subsequent inspection to calculate a close approximation of the rate of deterioration since the preceding inspection. A record of damage by fire, storm, collision, or woodpeckers where the damage is not considered sufficient at the time to warrant replacement will assist the inspector at subsequent inspections in deciding what action should then be taken.

The Technique of Inspection

The technical skill necessary for competent inspection of poles in line is not difficult to acquire, but it is generally under-emphasized in the training of inspectors. The external forms of deterioration can be readily observed and measured and the internal condition of a pole can be determined with reasonable accuracy by sounding and boring.

Sounding a pole means striking or tapping it lightly with a hatchet or similar tool. The tool should be held firmly but not rigidly and the blow should be delivered lightly with a forearm and wrist motion, and the face of the tool should meet the surface of the pole squarely. The sound emitted by the pole varies with its internal condition; a pole free from internal decay, insect damage or other imperfections sounds solid, whereas a decaying pole or one extensively riddled by insects sounds dull or hollow.

The natural resonance of a solid pole may be altered by the weight of a heavy load, or by heavy guying, or by a water soaked interior or surface, or by a shake within about two inches from the surface, or by large checks. The inspector therefore must acquire by experience the ability correctly to diagnose the sound he hears, and in all cases of doubt as to the internal condition of the pole he should use the increment borer.

The increment borer is a competent tool when properly handled. Like any cutting tool the edge should be protected from damage. When using the borer below the ground line care should always be taken to see that the pole surface at the point to be bored is free from dirt and grit. The borer should be turned with steadily applied force to avoid breaking the shaft. It should always be directed as nearly horizontal as possible (when boring standing poles) toward and to the center of the pole. In a properly taken boring the annual growth rings are approximately at right angles with the lengthwise axis of the core. The bore of the tool should always be clear of obstruction before starting the boring , for if not, the obstruction may cause the core of

wood to jam in the borer, or interfere with insertion of the extractor and if force is then used to pass the obstruction the almost invariable result is a plugged borer. The core is removed by inserting the extractor, making sure that the tip passes the outer end of the core freely; the extractor is then pressed in until it binds snugly but not tightly. The bit is then reversed about one half turn, and the extractor and core withdrawn together.

The increment borer core is a real sample of the wood at the location from which it is taken. If the wood is unaffected by fungi, it is flexible to a considerable degree and generally has a characteristic odor. The cedars have a spicy odor; pine has an odor of turpentine, although usually the creosote in treated pine masks the natural odor. The odor of cedar is usually fairly strong, but lack of odor need not arouse suspicion as to the condition of the wood provided the other characteristics of sound wood are present. If the wood is affected by fungi the core, even if it has been withdrawn without breaking, has practically no flexibility and breaks very easily; it usually has a distinct moldy or rotten wood smell. It is imperative, in the interest of saving poles, that enough borings should be taken in all cases of a deteriorating pole to determine the extent to which it is actually deteriorated.

The increment borer is of special utility in the inspection of creosoted southern pine and Douglas fir poles. A small percent of these poles may sound hollow when tested by tapping. In many cases the apparent hollowness is confined to less than one-fourth of the circumference. A very few poles may be found which sound hollow when tapped over the whole circumference. When the hollow "sound" appears to be confined in one quadrant of the pole, it may be due to localized decay in untreated inner sapwood, or to a "shake" within about two inches from the surface. In the latter case, there is usually a fairly wide check about in the middle of the hollow-sounding portion, and a core taken at either side of the check will be found to be solid except for a clean separation at the shake. These shakes are a natural characteristic of creosoted pine and Douglas fir poles and are not considered detrimental to the life or strength of the pole. When the hollowness is caused by decay a core taken at about the middle of the hollow-sounding region reveals the depth of penetration over the decay pocket, this depth being the present or ultimate thickness of solid "shell" over the region of decay. Additional borings should be taken at about the same level where the pole sounds solid. If by reason of greater penetration at these points it is evident that the decay will be confined to its present extent the deterioration is appraised on the basis of an enclosed pocket or on thickness of shell. If the depth of penetration at these points is less than the admissible shell thickness, indicating that eventually the pole will be inadequate, the immediate decision is based on judgment as to whether the pole should be reported for routine removal or for re-examination at the next regular inspection.

Inspection Procedure

It has been pointed out that the inspector's procedure should follow a general routine, varied according to circumstances, rather than adhere rigidly to a set of rules and mathematicl formulae. What follows here is a presentation of a procedure that has been found to facilitate the work of inspection and appraisal.

In general an inspector with one assistant is sufficient; in some cases two assistants will speed up the work. In other cases, notably where very little or no excavating need be done the assistant may not be needed regularly, and may then be engaged locally by the day.

The inspector should have all the necessary engineering information relating to the poles or the line he is to inspect. This information should include class of line, storm loading, and any prospective or planned changes in attachments, re-routing and the like within the next inspection interval. He should also have the previous inspection report if available.

The first approach to a pole should be with consideration as to whether, aside from any question of its physical condition, it should be retained in line in its present setting. As it stands the pole may be a public hazard, or interfere with convenient passage of traffic; it may lean out of line badly, it may be too short for present or planned purposes. Obviously, if a pole is to be replaced for reasons not associated with its physical condition, there would be no need to make a detailed inspection, unless it might be useful in deciding whether the pole could be used elsewhere.

The next step if the pole is to remain in line is to inspect it for damage above the ground line, that is for storm, fire, collision or woodpecker damage, and in the case of butt treated cedar poles for decayed sapwood or "shell rot". Some cedar poles, particularly those having thicker than average sapwood are likely to have only a thin shell covering a completely decayed sapwood after 12 to 15 years in service. This sapwood decay is a potential menace to linemen at work on the pole, and care should be taken to discover it.

The appropriate next step if the pole is not to be removed for damage above ground or for other reasons is to determine the internal condition above the ground line. A small percent of poles may be infested with carpenter ants or may have hollow heart or enclosed decay pockets above the ground line. Sounding by tapping lightly with the hatchet can usually be relied upon for detection of hollow heart, internal decay or ant workings. The extent of the damage should be determined by means of the increment borer. If the pole is solid or if not sufficiently deteriorated internally to warrant removal the inspector proceeds with ground line inspection when there is reason to suspect failure of the treatment or the presence of internal decay. Inspection of the ground line condition of pressure treated poles should be carried out on a sampling basis, judgment being made after examination of representative poles for a given suppliers production for a given year. These data have been branded at ten feet from the butt of all poles since 1931.

For purposes of ground line inspection, the soil should be removed from around the pole to a depth of about twelve inches, unless as the digging proceeds it is evident from the condition of the pole that no more needs to be done. In sandy or gravelly soils the excavation should be six to 12 inches deeper; in very wet, or swampy soils excavation is not usually needed. Inspection of the below-ground section of the pole is made in the same manner as above ground for internal decay, that is by sounding and using the increment borer. Where there has been external deterioration (decay) because of preservative failure, the examination is to determine the loss of wood by decay and the circumference of the core of sound wood remaining. This circumference can be determined in several ways with reasonable accuracy. The decayed and partially decayed wood can be removed as by scraping with some suitable dull edged tool, and then measuring the remaining circumference; or, the remaining circumference can be calculated by deducting from the original circumference, six times the average depth of decay as determined by probing at several points around the periphery pole. Preferably, the remaining circumference can be calculated from 3 or 4 borings equally spaced around the periphery; the unsound portion is discarded and only the remaining length to the pith center of the

pole is retained for measurement. This length then represents the radius of the sound core; the average of the borings so taken multiplied by 6 is approximately the circumference of the sound core. If this circumference is at least one inch greater than the required circumference at replacement, the pole may be considered suitable for ground line treatment. All exploratory holes are to be plugged with a decay resistant wood plug.

Synopsis of Pole Inspection Procedure

Crew - Inspector and one helper

Tools - Inspector's - increment borer, pole prod, hatchet, circumference tape, pole line records and previous inspection record, current inspection forms, wire conversion table and replacement circumference charts. Supplementary equipment, pencils, 6-inch rule.

Helper's - shovel or spade, light digging bar, plugs for filling increment borer holes.

Procedure - All poles. If pole is not to be removed, as for example for line change or respacing,

1. Examine entire above ground section

   1.1 for damage from collision, fire, storm, woodpeckers and for split top, breakage, etc.

   1.2 for inadequate height for clearance, either present or prospective, for interference with other services or structures, or with trees where trimming rights cannot be obtained, and for public hazard.

2. If pole is marked for removal because of damage (1.1) or for other reasons (1.2) or is not considered for re-use do no further work, otherwise proceed with inspection for internal condition above the ground line.

3. Sound the pole all around from close to the ground line upward as high as can be conveniently reached. If any internal decay, hollow or insect attack is suspected, determine extent of damage by additional careful sounding and use of the increment borer. If the pole is unfit for further service because of internal deterioration or extensive ant damage or if infested and no steps are to be taken to destroy the ants, mark the pole for replacement. Otherwise proceed with ground line inspection if the pole is cedar, western larch or creosoted pine or Douglas fir more than 20 years old except where the poles stand in swampy soil and are certain to be water soaked below the ground line, or where there is suspicion of preservative failure below ground line.

4. Excavate to a depth of about 12 inches all around unless before this has been done it is obvious that the pole is unfit to remain in line, in which case mark the pole for replacement.

5. Inspect the below-ground line section of the pole for external decay and for hollow heart and internal decay. If the pole is obviously considerably in excess of the replacement circumference, inspect first for its internal condition. If the pole is hollow or decayed and the thickness of sound shell is less than the minimum specified, or if it is clear that the deduction for hollow heart plus that to be made for external decay will reduce the equivalent circumference below the specified minimum, mark the pole for replacement. Otherwise proceed with determination of external decay. Locate the level of the deepest external decay and determine the equivalent circumference of good wood remaining. If the net circumference is less than the specified minimum making the pole undersize, mark the pole for undersize, mark the pole for prompt replacement, unless circumstances justify routine replacement. Plug all exploratory holes in poles which are to remain in place, using decay resistant (treated) wood plugs, or plugs made of black locust.

6. Estimate remaining pole life and date of, or years to, next inspection.

7. The inspection record should show --

   (a) the reason for condemnation.

   (b) the estimated circumference of good wood below ground line.

   (c) the next inspection date (year) or years to next inspection.

   The reason or reasons for condemnation should be definite. Thus, for reasons under (1) above, state --

   Damage, by collision, fire, storm, woodpeckers or split top, or

   Insufficient clearance, trees or other services, or

   Line change

   for reasons under (3) above, state hollow heart, internal decay, or ants or termites above ground,

   for reasons under (5) above, state hollow heart, external decay (preservative failure), ants, termites, or undersize, as the case may be.

   The estimate of remaining good wood should be recorded because it will be of material assistance at the next inspection in determining the rate of deterioration and in estimating remaining life.

   The next inspection date or years to next inspection should be recorded because it will assist greatly in planning subsequent inspection work load.

GROUND LINE TREATMENT

This is a supplementary treatment to be applied only when

(a) the portion of the pole above the ground appears to be adequate for at least 5 years and does not offer unusual hazard to men climbing or working on the pole.

(b) there is at least one inch of good wood in excess of the replacement circumference.

Preservatives

The preservatives suitable for this work are,

(a) Coal Tar Creosote for Non-pressure Treatments, per AWPA Standard Specification P 7-54

(b) Penta-petroleum Solution containing 5% of pentachlorophenol, per AWPA Standard Specification P 8 and P 9.

The creosote can be obtained in portable quantities up to 55 gallons (in drums); the pentachlorophenol can be obtained in dry (crystal) form and mixed with petroleum (such as household fuel oil) or preferably it can be purchased in a concentrated liquid (oil) form for further dilution in petroleum as desired.

Application of the Preservative

Either of these preservatives can be applied at atmospheric temperature above freezing (preferably above 50°) through any convenient means, such as a watering can, without the spray head, when only a few poles are to be treated; or with an ordinary garden pressure sprayer with the spray nozzle removed; or an Indian fire pump or its equivalent. Pressure however is not necessary.

In a large scale operation it will be advantageous to provide equipment to transport and apply the preservative. There is no standard equipment however; it is a matter of adaptation of available apparatus designed for somewhat similar use.

Preparation of the Pole for Treatment

When the thickness of decayed wood on the surface of the pole exceeds about one-half of an inch, it should be removed by scraping with a dull edged tool down to firm wood. Care should be taken to remove as little firm or sound wood as practicable.

It is not generally necessary to delay application of the preservative until the pole surface has dried.

Procedure for Ground Line Treatment (External)

The treatment is preferably and for economic reasons done in connection with inspection. On completing the inspection, the excavation is loosely refilled to about half its original depth. The soil is then pressed away from the entire periphery of the pole to about the depth of the refill, thus making a V-shaped trench surrounding the

pole. Approximately 2 quarts of the preservative are then applied against and all around the pole at about 12 inches above the ground level, especial care being taken that the oil enters into any checks and exposed decay pockets. Back filling of the excavation is then completed, taking care that the preservative which has flowed into the trench stays there. On completion of the back fill, which may be tamped as desired, another V-shaped trench is formed to about the upper level of the preceding one. Another two quarts of preservative are applied as before, after which, the trench is closed by pressing the soil slowly against the pole.

Procedure for Internal Treatment

Internal treatment may be necessary to combat infestation of carpenter ants and subterranean termites, especially in western red cedar.

Where these insects are prevalent in a region they are usually to be found in a few poles, and unless exterminated are capable of very materially weakening a pole.

The external ground line treatment generally will suffice to destroy an infestation of subterranean and damp wood termites, but it may be considered good practice to apply an internal treatment as well, using the same preservatives although creosote, because of its strong fumes appears to reach any insects which may not be actually in contact with the oil itself.

The preservative is conveniently introduced through two or more increment borer holes, bored to intersect the inner galleries or chambers of the insects. These are intricately connected so that penetrance of any of them usually gives sufficient access to the whole labyrinth. An ordinary heavy grease gun, like those used in garages, provided with an extended nozzle of about 4 inches length, has been used satisfactorily for injecting the preservative. Approximately one pint of the oil injected into each hole has been found to be completely effective. The holes bored for this treatment need not be plugged.

This has been a presentation of some of the important aspects of pole design, procurement, use, and maintenance. It has not been practicable to cover the subjects in complete detail, and it is likely some aspects may have been omitted. Consequently, a discussion period is now in order.

ELEMENTS AFFECTING CONSTRUCTION OF POWER PLANTS

By Ivan A. Bosman

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
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RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

ELEMENTS AFFECTING CONSTRUCTION OF POWER PLANTS

Ivan A. Bosman

This subject covers a good deal of ground and the discussion will be limited to the planning and methods used in selecting sites for power plants. We are concerned with three types of plants, Hydro, Internal Combustion and Steam.

HYDRO ELECTRIC PLANT

We shall consider a hydro plant first. Before a loan for a hydro plant is made a "Hydro-Electric Potentialities Survey" must be submitted. The board of directors selects a qualified project engineer who may or may not be the preloan engineer. The "Hydro-Electric Potentialities Survey" does not go into design detail and if in our judgment additional factual information is required before a loan can be made a more detailed report is requested.

All previous investigations that have been made are reviewed and present investigation of the site is made, giving reasons and recommendations for plan of development selected. Some of the main headings that are included in such reports are:

a. Topography

b. Hydrology

c. Geology

d. Federal and Territorial Jurisdiction

Topography

A topographic map of the site under consideration which will show natural features, man-made features, and location of materials which can be incorporated in the dam. The topographic map should have five-foot contours.

Hydrology

A study is made of the stream flow of the stream involved. The engineer investigates all pertinent data including climate, rainfall, snowfall, temperature variations, ice conditions, wind direction, and amount of evaporation. A study of the stream flow at the site under consideration is made showing variation during seasons of the year. He also prepares hydrographs of the average, minimum and maximum years as well as duration curves. Power duration curves are prepared to show the initial and ultimate installations of generating equipment.

Geology

The engineer is expected to study the general geology of the areas. This is done by core drilling, test pits and any other methods that will show the strata of the ground in the area considered for construction of the dam. Soils in the area have to be analyzed for possible use as dam building material. The engineer is expected to prepare a proposed plan of construction showing details such as material, size, shape, length, height, and capacity, etc. He is expected to give reasons for using the particular design considered.

Federal and Territorial Jurisdiction

The engineer shall look into the need for permits, licenses, franchises or any other authorization that the Owner might be required to obtain from the agencies having control. Some of the agencies are Federal Power Commission, United States Geological Survey, Forest Service, Fish and Wildlife Servioe, Bureau of Reclamation,

National Park Service, and the Territorial Government of Alaska. There may be some local Government requirements that may also have to be satisfied. It is the responsibility of the engineer and project attorney to look into the matter of permits and instruct the Owner how to proceed in obtaining them.

After the engineer studies the above items, he supplements his thinking with drawings and data on the following:

a. A mass-flow diagram or reservoir operation diagram showing the effect of power production if carry-over storage is provided. The effect of pondage on power peaking shall also be illustrated or described.

b. Curves showing the effect on stream flow by use of storage or pondage for power purposes, including peaking, particularly where prior water rights might be affected.

c. An area-capacity curve of the reservoir indicating usable and dead storage.

d. A profile of the river for the reach between the upper limits of the reservoir to a point one-half mile downstream of the damsite.

e. Economic Details:

(1) A feasibility study based upon the adequacy of the stream and the plant to develop sufficient power to supply the electric requirements of the system as indicated by existing and estimated future load data supplied to the Engineer by the Owner.

(2) Recommendations as to the type and size of dam or diversion dam; penstock, flow line and/or canal; and generating units which may be necessary to provide for the load requirements of the power system for the initial and ultimate installation.

(3) Recommendations as to the most practicable method of operation to adapt the plant production to the power system requirements.

(4) An estimate of the quantity of material and the unit cost thereof for developing each Structure, and an estimate of the cost of the equipment to be installed, all in accordance with the Federal Power Commission Uniform System of Accounts, including the cost of land, water rights, licenses, franchises and any other relevant items of expense.

(5) An estimate of the average annual charges, including operation and maintenance, taxes, insurance, public liability, FPC charges, interest and amortization of the loan and any other items of annual expense that may be incurred.

The engineer then submits five copies of this report to the Owner and Administrator for approval. The Owner or the Administrator may ask the Engineer to amplify or supplement the report if necessary.

STEAM ELECTRIC PLANTS

The site selection report for a steam plant is one of the requirements of the Engineering Service Contract (REA Form 211). The precondition of a steam-electric generating plant is that water and fuel be available. Other factors, too, must be carefully weighed in the selection of a site for such a plant. In general, the considerations are as follows:

a. Water supply

b. Topography

c. Subsoil conditions

d. Fuel (supply and storage)

e. Relation of plant site to electrical load center

f. Transportation facilities

g. Adequacy of site for expansion

h. Disposal of waste products (fly ash, ash)

j. Amenities for employees

k. Taxes

No one site being ideally situated in respect of all the considerations cited above, several suitable sites should be selected and options to purchase should be secured on all of them. This will in most cases prevent exorbitant price rises for the real estate involved. A good source of information concerning available sites are the offices of the transportation companies serving the vicinity of the proposed plant. Care, however, must be exercised in the evaluation of information so obtained where competing railroads or barge lines serving different coal fields supply the data.

Water Supply

Water is used in the steam-electric generating plant for two purposes: (1) for cooling and (2) for replacing the loss of water in the steam cycle or in the cooling system if cooling towers are used. Sources of water are generally rivers, lakes and in exceptional cases, wells or the sea.

1. For condenser cooling purposes, ample quantities of cold water are necessary in the immediate vicinity of the plant. If the cooling water is not recirculated to a cooling tower, a site adjacent to the sea, a fairly large lake or a flowing river becomes mandatory. In exceptional cases, the river may occasionally run dry on the surface of the ground, forcing reliance upon large capacity wells to tap the underground cool water supply.

2. When the plant site is beside the sea, a lake or river, variations in the level of the water source must be determined, including maximum tides, high water, flood and drouth levels.

3. With a water supply from a source of sufficient depth, such as deep rivers and lakes, the site should permit the intake to be located below the thermocline (plane below which the water temperature remains constant regardless of atmospheric temperature changes). This plane is normally at a depth of about 15 feet below water level, in the case of fresh water lakes. The water below the thermocline is often 5 to 15° F cooler than surface water.

4. Where sewage or industrial wastes are emptied into rivers upstream or into lakes in the vicinity of the proposed plant, the water must be checked for the presence of acids injurious to plant equipment, molasses, algae or bacteria promoting growth of algae whose presence may lead to serious problems of corrosion or clogging when the condensers are in service.

5. The site should be such that water can be discharged without the danger of recirculation except in northern climates where provisions must be made for recirculation during freezing weather to keep the intake open.

6. The water from rivers or lakes is usually taken into the plant through a conduit with the pumps located either at the water's edge or at the plant itself and discharged through another conduit. The pumping head imposed on the circulating water pumps must always be considered and perhaps evaluated. If it is unusually large, the possibility of reclaiming a portion of it by syphons or other means should be determined as well as the cost of doing so.

7. Where the natural flow of water is limited, cooling towers or spray ponds are used.

8. The boiler feed-make-up water is usually taken from the cooling (circulating) water supply. It is then filtered, chemically treated, evaporated and introduced into the steam cycle. In exceptional cases it may be taken from wells. In arid regions or regions of bad surface water conditions, a thorough investigation will be required. Since cooling towers are frequently used in such regions, the water investigations should be carried out under the direction of a specialist versed in this type of work.

Topography

In determining plant sites, the use of topographical maps of the Unites States Geological Survey ("Topographical Sheets") aerial photographs, and Corps of Engineers' river maps are of high value.

Level ground of sufficient area for the ultimate plant development, including ancillary structures and a parking area for employees should be available in order that earth moving costs will be at a minimum. Plants have been located on hillsides, but great care must be exercised to take the best possible advantage of the terrain so as to minimize earth-moving. In such locations the layout of transmission lines must be determined so that especially expensive construction may be evaluated.

A factor sometimes overlooked where hills adjoin the plant are prevailing winds. They may influence chimney draft considerably and create a nuisance problem due to down-wash from the plant stacks. This becomes especially important in the vicinity

of settlements as the neighbors already prone to object to plant noises, may complain that their properties are further damaged by the intolerable conditions arising from coal dust from the storage area and fly ash and flue gases from the stack. Prevailing winds should also be taken into account when locating the plant step-up substation. The latter must be so located in relation to the coal stocking area that the blowing of coal dust onto the substation is minimized.

Prevailing winds also have a marked effect on plants equipped with cooling towers as spray from the towers may be carried quite a distance. It is important, therefore, to locate the towers in such a manner that no spray can be carried by the prevailing wind to any part of the plant where outdoor equipment, especially the substation, could be adversely affected, or to any neighboring property.

All these considerations must be studied most carefully where seaside sites seem to be advantageous, because of the serious effect of the fogs forming in such locations upon all electrical equipment as well as upon steel structures.

Except in seaside areas the plant should be located if at all possible directly on the water's edge. The presence of highways, railroads or other structures skirting the water front must be given serious consideration. The crossing of these obstacles by circulating water tunnels, spur tracks and overhead wires requires permits or easements and results in considerably increased cost of the plant in many instances. The plant site including the essential means of access by road (and by rail if solid fuel is used) should be at least five feet above highest recorded flood level. If due to unavoidable circumstances, the surface or ground water level can ever rise above the lowest floor level in the plant, the plant in itself must be calculated for buoyancy and provisions must be made to bulkhead all openings to five feet above the highest recorded flood stage. Furthermore, regardless of plant location the plant design will require checking with the Civil Aeronautics Administration as to the permissible height of the stack, required airplane warning lights, etc.

Subsoil Conditions

The State Geologist and the United States Geological Survey must be consulted to ascertain the probable subsurface conditions which will exist in the vicinity of each site considered. Subsurface structures may easily be the most expensive part of a plant, and the possibility of later subsidence of the site when loaded by the plant must always be investigated by geologists.

When it has been determined that future hazards can arise on the site a thorough study of the subsurface strata should be undertaken at all sites under option or at the sites which other considerations indicate to be the most desirable. In most cases, a reliable estimate of per unit cost cannot be made without deep test borings and the results of these drillings should be authoritatively interpreted by a recognized laboratory. Sites requiring long piles to reach a firm subbase should, if possible, be avoided. Sites on alluvial sand and silt require spread foundations which are expensive and tend to differential settlement. Quicksand especially poses problems of this nature and like gumbo soils, should be critically examined. When gravel beds under the site are encountered their depth should be carefully determined to see whether or not they provide adequate support for heavy loads. In glacial gravel deposits, nests of boulders may be present rendering construction difficult and expensive. Clay and sandy soils may require friction piling. In general, no site should be considered where there is any possibility of settlement when later additions to the plant are made. In an economic comparison of sites the considerations mentioned must be thoroughly discussed.

Fuel (Supply and Storage)

As REA-financed plants are amortized on a 35-year basis it is vitally important that an adequate fuel supply for the ultimate development of the plant be assured over the life of the loan. While not absolutely necessary, it is to the best interest of the Owner that more than one type of fuel be available. This usually results in keeping alive competition between different fuels and thus will allow the borrower to use the fuel which at the time of purchase is the most economical. If the advantages of some particular site are outstanding in all other respects, but only one source of fuel is available at that site, the long-term assurance of the availability of that fuel and its cost must be most critically examined.

Solid and liquid fuels are normally received by railroad, truck or barge, and gaseous fuels by pipe line. Adequate unloading facilities for solid and liquid fuels such as car shakers and dumps, hoppers, clam shell drag-lines, oil pumps and in northern climates, car thawing sheds and oil heaters, must be provided, with the necessary special switching and trackage. Where cheap water transportation is available for solid fuels the storage area and trackage for emergency rail shipments in winter, will be important and lastly, where liquid fuels are available by water and by rail oil tanks, pipe lines, car and barge unloading equipment and pumping facilities for both methods of transportation must be determined as to area necessary and cost as well as the trackage and switching required for rail shipment. Special attention should be directed to assure that unloading facilities are above flood level. Storage for solid fuels requires an area of sufficient size to store enough supplies for at least three months' operation of the plant. Where fuel is brought in by water, an eight months' supply in northern climates, becomes minimum. Determination of the permissible height of the storage pile must be made as this will vary with type of fuel, due to the varying risk of spontaneous combustion. Provision should be made in plant layouts and in estimates of plant capital costs and operating expense so that water borne and rail borne coal can be unloaded, delivered either to storage or to the bunkers, and compacted economically. Even in plants which are intended to use liquid or gaseous fuels it is necessary to consider that, in the future, it may become necessary or economical to burn coal. This may happen either by gas or oil fields becoming exhausted or by economic dislocations making fuels other than coal prohibitively expensive. Thus, if there is even a remote chance of coal ever being used it is imperative that a site be selected which affords a sufficiently large area for storage of coal and disposal of ash.

Storage for liquid fuels is provided by tanks. Storage for a six weeks' supply is considered satisfactory in most cases, but special conditions may require a larger storage. Particular attention must be given to provisions such as dikes, for safeguarding the property from eventual rupture of a tank. Where oil is used as a standby or for lighting off pulverized fuel boilers, a few days' supply for each unit may prove satisfactory.

Plant Site and Load Center

Transmission lines with their associated substations are costly. The ideal plant site, therefore, is one requiring the least amount of transmission from the plant to the user, i. e., a site at the load center. The importance of this factor varies with the load density, being greatest in urban centers and diminishing with the small load density of rural systems.

As it is rarely feasible to locate a steam plant having the best water supply, topography, subsoil conditions and fuel supply, exactly at, or close to, the load center of the system to be supplied with energy, an economic comparison of the total project capital cost and operating expenses for each of the various sites including the necessary transmission facilities must be made, with special consideration given to the high cost of river crossings. In estimating operating expense, consideration

must, of course, be given to the economic evaluation of transmission losses and regulation of transmission lines as between the various sites. In locations at the foot of a hill, serious attention must be paid to methods of routing transmission circuits out of the plant substation and to the adequacy of the area selected for the substation.

Transportation Facilities

The plant receives not only fuel via rail, barge or truck, but also, during periods of construction, heavy equipment.

In case water transportation is contemplated, docking facilities will have to be provided. This may require negotiations with, and construction permits from the Corps of Engineers. It is advisable to make a preliminary check with that agency to explore its standing on docking facilities. Furthermore, barge unloading facilities must be provided. As our northern waters are ice bound during part of the year, alternative transportation facilities must be provided where shipping is suspended at certain times.

Railroads in the vicinity of the plant sites should be approached to ascertain freight rates to the different sites selected as the rates may vary considerably between them. Adequate switching tracks must be provided to receive and store the maximum number of cars which may be delivered at any one time, when the plant is expanded to its ultimate size. A transformer transfer track at the substation is a convenience in handling heavy power transformers; thus consideration should be given to a site layout which facilitates such an approach to the railroad track that the transfer of a transformer from a flat car to the transfer truck will be easy. Spur tracks for plant services should be laid out in such a manner that they do not preclude future expansion of the substation, that they are not in the way of outgoing high tension lines and that they do not require a multiplicity of grade crossings outside of the immediate plant area. Where trucking is necessary and heavy equipment must be handled into the plant in this manner, care should be exercised to make sure that highway bridges are sufficiently strong to take the heaviest load expected. State highway departments are a good source of such information.

Adequacy of Site for Expansion

Power plants grow with the systems they serve. With shifting load centers, however, additional capacity after the initial installation, may have to be located remote from the original plant. Even though it may be foreseen that this will occur, sufficient real estate for expansion must be provided at the initial site because of unforeseen developments which may dictate expansion of the original plant as a later step.

Of course, care should be exercised that in the planning of ultimate station capacity and, therefore, of size of plant site, the limits of the water supply be not exceeded by the demand for circulating water. If the natural water supply is limited, the maximum plant capacity which can be served by it must be stated in the site report and the other sites which may require development to meet the maximum ultimate system loads must receive such attention as will enable the owner to visualize clearly the problems he will meet during the life of his property.

Special attention should be given to expansion of substation facilities, particularly at the higher voltages from 69 kv up and to the feasibility of additional lines issuing from the substation. The latter consideration may require ingenuity in the use of dead end and other special structures.

Waste Disposal

In contrast to other industrial installations a power plant has few fluid wastes, but a large quantity of gaseous and, if coal burning, solid wastes.

The disposal of the solid products of combustion, ash and fly ash, is a serious problem where low areas for fill are inadequate for long-term storage. This problem is of the order of the lifetime of the plant. A South American plant laid out to burn coal rich in ash had to be converted to oil fuel after about 15 years because all areas low enough to store ash had become filled up. It is often possible to sell the ash from stoker-fired boilers whereas slag and fly ash from pulverized coal-fired plants must be disposed of at some cost to the owner. Where the latter wastes have to be hauled away to distant fill areas the cost for such transportation has to be figured in the cost of operation and may become a factor in the selection of a site.

State and federal authorities must be consulted in regard to contamination of streams, lakes, surface waters and the sea by waste products from the plant.

The gaseous wastes such as sulphur in the flue gases and carbon dioxide (as well as fly ash) may require special treatment equipment (dust catchers, scrubbers, CO_2 inverters) to reduce their nuisance effects upon nearby settlements. This raises the plant investment and may favor a plant location more remote from neighbors than one close to a village or town. The effects of such stack discharges upon agricultural and horticultural operations and upon trees must also be considered.

Amenities for Employees

A consideration often neglected is the recruiting of employees for operation and maintenance of the station. Adequate housing for operators should be available at reasonable prices; good schools, stores, churches should be near the plant and good roads giving easy access to the plant at all times. As most employees have automobiles adequate parking areas must be provided. The results of not giving sufficient attention to this subject may render it impossible to hire competent personnel at the prevailing wage rates.

Taxes

A further factor influencing the selection of a proper plant site is the tax rate in those states which levy property taxes on cooperatives. Two elements enter into the calculation of the annual tax burden: the percentage of the plant value at which the property is assessed and the rate per hundred dollars of assessed value which is levied against the property. As these factors may vary greatly from county to county and from state to state, they must be taken into account in the calculation of the fixed charges against the plant. The engineer and the Owner's attorney should collaborate in advising the Owner regarding current and future taxation for each site considered.

Since State laws on taxation are subject to amendment or repeal the assumption that full tax rates may be levied in later years should always be made in calculating long-term average tax levels.

Site Report

A site report should discuss in detail all the foregoing points for each site under consideration carefully weighing each point and balancing one against the other. Tabulations showing quantitatively as well as qualitatively the various components going into the evaluation of the different sites must be a part of the report. Pertinent topography should be included, as well as copies of correspondence from railroads and other transportation agencies, fuel suppliers, State Geologists, United States Geological Survey, Civil Aeronautics Administration, United States Corps of Engineers, also aerial and terrestrial photographs of the sites, etc. The final part of the report should sum up the reasons why a certain site is considered superior to all others.

The report should always be prepared having in mind that those reviewing it must be so fully informed that they can reach independent conclusions regarding each factor considered and the final recommendation.

Internal Combustion Power Plants

Site selection for an Internal Combustion plant is similar to that of a steam plant. Those that apply are listed below:

a. Water supply

b. Topography

c. Fuel

d. Relation of site to electrical load center

e. Adequacy of site for expansion

f. Amenities for employees

g. Taxes

In general the same elements apply to both types of plants.

Most Internal Combustion plants are cooled with cooling towers or radiators and the water supply is most generally shallow or deep wells. The engineer should investigate existing wells in the vicinity by checking with the State Geologist who usually has logs of wells drilled. It may be necessary on some occasions to drill a test well to determine the location of water bearing strata.

The plant should be located on a site that has good drainage and also good soil for foundations. The engineer should examine fuel supply carefully as Internal Combustion engines can burn both or either gas or oil. The location of gas lines, existing or proposed, should be considered in selecting the plant site. Transportation facilities, both highway and railroad should also have some bearing on location of plant as trucking fuel oil versus rail transportation may have a great deal of effect on the operation of the plant in the future.

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INTERNAL COMBUSTION ENGINES AND THEIR USE IN GENERATING ELECTRIC POWER

By Everett J. Raushenberger, Head
Internal Combustion Plants Section
Electric Engineering Division

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RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

INTERNAL COMBUSTION ENGINES AND THEIR USE IN GENERATING ELECTRIC POWER

EVERETT J. RAUSHENBERGER

INTRODUCTION

The first use of the internal combustion engine as a prime mover to generate electricity for systems of REA borrowers began approximately 16 years ago. Since then, this type of engine has proven to be valuable in supplying electric energy for many systems of REA borrowers. I would like to tell you about the elements and characteristics of internal combustion engines and about the components of an internal combustion engine-generator plant with a view of making your visits to such plants more interesting.

ELEMENTS OF INTERNAL COMBUSTION ENGINES

The internal combustion engines differ from steam engines or turbines in that the fuel burns or combustion takes place within the engine itself, whereas in a steam engine or turbine the fuel is burned in a boiler outside the engine, which transfers the heat of the fuel to a medium, usually water, which transmits energy in the form of steam to the engine or turbine. That is external combustion.

An internal combustion engine (shown in figure 1) consists of a cylinder in which the fuel mixed with air is fired; a piston to receive the expansive force of the burning fuel and convert it into mechanical motion, and a crankshaft to turn the up-and-down motion of pistons into rotating motion suitable for driving an electric generator. In addition, suitable valves or ports must control the flow of air, fuel and exhaust gas and there must be a reliable means for igniting the fuel.

All internal combustion engines operate in the same general way. Each cycle, or series of events taking place in the cylinder involves four steps: (1) Cylinder is charged. (2) Charge is compressed and ignited. (3) Burning charge expands, pushing a piston. And (4) burned gas is exhausted so the cylinder can be recharged.

Some internal combustion engines operate in a four-stroke cycle, others on a two-stroke cycle. This simply means that, in the first case (figure 2) four strokes or two complete revolutions are needed for the full cycle of intake, compression, expansion and exhaust. In the second case (figure 3) the same operation is accomplished in two strokes or one revolution. Two cycle engines require a compressor to provide air slightly above atmosphere to blow out or scavenge the exhaust gases and recharge the cylinder with air.

CHARACTERISTICS OF INTERNAL COMBUSTION ENGINES

There are nine basic kinds of internal combustion engines. Although in major respects they differ, namely, in the fuels handled; the method of mixture of fuel and air; how the charge is compressed and how the charge is ignited. These differences account for variations in efficiency, performance and cost, and in application. These nine types are divided into two groups:

Otto Cycle

The first group consists of those engines in which fuel and air mixing occurs before

compression. The most familiar engines of this group are the gasoline engine and the gas engine. The cycle of events of these engines is shown in figure 4. The compression of the fuel-air mixture increases its temperature. The temperature may be not enough to self-ignite the mixture before the end of the compression stroke. This causes preignition and detonation or "knocking" and results in loss of power. This method of burning fuel-air mixtures is restricted to engines of low compression pressures. Because Otto and Langen of Dentz, Germany were the first to build a commercial engine based on these principles, all such engines are called "Otto-cycle" engines.

Diesel Cycle

The second group consists of those engines in which the fuel and air are mixed within the cylinder near the end of the compression stroke and the mixture is ignited by the heat of compression. This group is called "Diesel Engines" bearing the name of Rudolf Diesel, who developed in the 1890's in Germany the basic theory for such types of engines. The most familiar engines of this group are the diesel engines, gas-diesel engines and dual-fuel engines. The cycle of events of these engines is shown in figure 5.

Diesel Engines

In a typical diesel engine the air is compressed to about 450 psi, which raises the temperature to about 1000° Fahrenheit. The finely atomized oil is sprayed into this "red-hot" air; it ignites and burns. In the diesel engine the high compression pressures are needed for reliable ignition. Typical compression pressures in diesel engines range from 450 to 600 psi. The firing pressures range from about 600-1200 psi.

Gas Diesel Engines

After the air is compressed the gas is injected at about 1000-1100 psi pressure. To stabilize the combustion a small quantity of pilot oil is also injected.

Dual Fuel Engines

The dual-fuel engine differs from the gas-diesel engine in that it can automatically switch from gas to oil or from oil to gas under load and can burn combinations of quantities of oil and gas. The difference in fuel-air ratios accounts for the ignition behavior between the dual-fuel and the gasoline engines. The gasoline engine operates with a nearly "perfect" mixture, readily ignited and explosive in burning. The dual-fuel engine, being essentially a diesel engine, operates with high excess air, or a "lean" mixture. The burning starts and is maintained by igniting pilot oil into the heated mixture.

Compression Ratio

The volume of the cylinder at the beginning of a stroke, divided by the volume of the cylinder at the end of the stroke, is the compression ratio. The pressures at the end of compression are roughly proportional to the compression ratio. It is important for two reasons:

First: Theoretically, the higher the compression, the more efficient the engine.

Second: In general, the higher the compression ratio, the stronger and heavier must be the engine.

In engines where the fuel and air is mixed before compression, the nature of the fuel imposes a limit on the compression ratio. In ordinary gasoline engines the compression ratio is six or seven to one. With finer quality fuels such as 100 octane aviation gasoline, the compression ratio ranges from nine to one. In diesel engines, the compression ratio ranges from fourteen to fifteen to one.

Brake Horse Power

The actual output of an engine, that is, its brake horsepower, is related to the number of cylinders, the diameter and stroke of the pistons, the engine speed and a theoretical factor called "brake mean effective pressure", which is abbreviated as bmep. Brake mean effective pressure represents the average pressure on the piston throughout the power stroke reduced by the amount needed to overcome friction losses. It cannot be measured directly but is calculated from the test date in measuring the brake horsepower of an engine. Bmep is used by operating men and designers as a means of comparing various engine ratings. A simple formula for calculating brake horse power for an engine is:

$$BHP = \frac{PLAN}{33,000} \times n$$

in which

P = brake mean effective pressure, psi
L = stroke of piston, ft.
A = the net piston area, sq. ins.
N = number of power strokes per minute which is equavalent to the rotative speed for two cycle engines; and one-half rotative speed for four cycle engines

n = number of cylinders

Classification of Internal Combustion Engines

The many improvements and new designs in these various components of the internal combustion engines composing the basic formula for brake horse power have increased the horsepower of the engine and its application in new fields of service. These changes may be used to classify the engines in several ways: (1) type of fuel burned, (2) method of fuel injection, (3) operating cycle, (4) piston action, (5) piston connection, (6) cylinder arrangement, and (7) speed.

Type of Fuel - The most common fuels for internal combustion engines are gasoline, natural gas, oil and combinations of gas and oil. These fuels are classified as hydrocarbons and consist of various combinations of hydrogen and carbon. This type of fuel is injected into the engine cylinder where it mixes with the oxygen of the air, the hydrocarbons break up into hydrogen and carbon, each of which unites with the necessary oxygen to support a combustible mixture.

Method of Fuel Injection - Most modern diesel engines use solid or mechanical-injection-fuel systems, consisting of a high pressure pump and nozzle which inject minute quantities of atomized fuel at close time limits into the cylinder at pressures of 2500 to

3000 psi or higher. The early diesel engine used blasts of highly compressed air to blow fuel into the cylinder. With the development of the solid-injection systems. the air-injection engine is rapidly disappearing.

Operating Cycle - As mentioned before, internal combustion engines can be divided into two groups based on the number of piston strokes per cycle of operation. Four cycle engines are further classified as to the method of supplying air to the engine. If the air is taken at atmospheric pressure the engine is said to be a "normal aspirated" engine. If air is forced into the cylinder by a supercharger or turbocharger at pressure substantially above atmospheric (up to 10 psi or more) the engine is classified as a supercharged engine. Two cycle engines are further classified according to the method of supplying air slightly above atmospheric pressure to the cylinder to blow out the exhaust gases and to fill the cylinder with fresh air. This scavenging air is obtained in some two-cycle engines by using the crank case and the underside of the piston as a compressor. This method is known as crank case scavenging. Scavenging air in other engines is supplied by blowers and pumps; these methods are known as blower scavenging or pump scavenging.

Piston Action - An engine's piston action may be classified by three methods: First, Single acting engines use only one end of the cylinder and one face of the piston to develop power. The working space is at the end of the piston away from the crankshaft and power is developed on the down stroke. Most general purpose engines are single acting. Second, Double acting engines use both ends of the cylinder and both faces of the piston to develop power on the up stroke as well as on the down stroke. The construction is complicated; usually, double-acting engines are built only in large and comparatively low-speed units, generally to power motor ships. A section through the cylinder of a double-acting engine is shown in figure 6. Third, Opposed-piston engines have cylinders in each of which two pistons travel in opposite directions as in figure 7. The combustion space is in the middle of the cylinder between the pistons. There are two crankshafts; the upper pistons drive one, the lower pistons the other. Each piston is single-acting. This type of engine because of its weight, volume and space per horsepower is used to propel submarines and drive locomotives.

Piston Connections - The piston may be connected to the upper end of the connecting rod either directly ("trunk-piston" type), or indirectly ("crosshead" type). In trunk-piston engines a horizontal pin within the piston is encircled by the upper end of the connecting rod. This is the most common construction. In crosshead-type engines, the piston fastens to a vertical piston rod whose lower end is attached to a sliding member called a "crosshead", which slides up and down in guides. The crosshead carries a crosshead pin which is encircled by the upper end of the connecting rod. This construction is required in double-acting engines, as shown in figure 6. It is used in construction of some, large, slow-speed, single acting engines.

Cylinder Arrangements - An internal combustion engine has its cylinders usually arranged in one of four ways: First, A Cylinder-in-line arrangement is the simplest and most common arrangement, with all cylinders arranged vertically in line. This construction is used for engines having up to twelve cylinders. Second, A V-Arrangement of cylinders is shown in figure 8. If an engine has more than eight-cylinders it becomes difficult to make a sufficiently rigid frame and crankshaft with an in-line-arrangement. Also, the engine becomes quite long and takes up considerable space. The V-arrangement, with two connecting rods attached to each crankpin, permits reducing the engine length by about one-half, thus making it more rigid, with a stiff crankshaft. Engines with V-arrangement usually have eight, twelve or sixteen cylinders. The most common angles between the banks of cylinders being $40°$ & $75°$. Third, A flat-

engine, is a V-engine with the angle between the banks increased to 180 degrees. This arrangement is used with restricted head room, as in trucks, busses and rail cars. Fourth, in a radial engine, figure 8, all the cylinders are symmetrical arranged with longitudinal axis on radii of a circle; by which such an arrangement receives its name. The connecting rods of all pistons work on a single crankpin, which rotates around the center of the circle. By attaching the connecting rods to a master disk surrounding the crankpin, as many as twelve cylinders have been made to work on a single crankpin. Radial engines require a minimum of floor space. As many as 120 radial engines have been installed in a single plant.

Speed - Internal combustion engines may be divided into four classes according to speed; low speed, medium speed, medium-high speed, and high speed. Although no precise definitions of these terms have been established, most diesel engine catalogues classify engines operating at speeds of the ranges shown below:

Slow speed, range under 350 RPM
Medium speed, range 350 to 700 RPM
Medium-high speed, range 700 to 1200 RPM
High speed, range 1200-1800 RPM

Automotive engines often run at speeds faster than 1200 RPM, but the majority of diesel engines run between 200 and 1200 RPM.

Service Requirement - The developments in the later years of diesel engines has permitted this type of engine to be used in many fields of service. Service requirements may serve to classify an engine, but basically the type of engine is not determined by them. Engines may be classified for the following types of service; stationary, marine, railway, automotive, aircraft, power shovels, cranes, etc.

AUXILIARY EQUIPMENT IN TYPICAL DIESEL PLANT

The schematic diagram shown in figure 10 shows the auxiliary equipment serving the diesel engine in a typical stationary plant. In smaller engine installations some of these auxiliaries are mounted in the engine. In larger plants, auxiliaries are mounted on their own bases, the arrangement and location of the auxiliaries depends on the plant conditions. The general function of the auxiliaries are:

Fuel System - provides storage tanks for the supply of fuel oil. Pumps are required to transfer oil from storage tanks to the day tanks located near the engine, to the engine and to the strainers and filters need to insure clean fuel.

Intake Air System - provides air for combustion. It consists of piping from the source of fresh air to the engine manifold, with a filter to remove dust and other harmful impurities. It may include a silencer to subdue noises from air-supply pulsations.

Exhaust Air System - consists of a pipe leading from the engine to a point where the exhaust gases can be discharged without danger and annoyance. It includes a silencer to reduce noise from the exhaust pulsations and may include a heater or a boiler to recover some of the heat from the exhaust gases.

Starting System - provides motive power to turn the engine through several cycles until firing starts and the unit runs on its own power. Usually compressed air is used.

Lubrication System - delivers oil to the rubbing surface of the engine. It includes a sump tank, pumps for delivering oil to the engine and for circulation of oil under pressure to points needing lubrication, strainers and filters to remove foreign matter that might damage the engine. It includes an oil cooler to keep the lubricating oil at desired temperature.

Cooling System - removes part of the heat of combustion in the engine cylinder, keeping metal temperatures in and around the combustion space at a reasonable level. A pump circulates water through cylinder and head jackets; this water picks up heat and carries it away. The jacket water system is of a closed circuit in which a pump circulates treated water, with scale forming properties removed. The heat from the treated water is transferred to raw water through a heat exchanger. Such a system eliminates scaling and corrosion of the cylinder and head jackets of the engine.

Controls and Instruments - controls are installed in the various flow circuits to regulate and maintain the operation of the engine within prescribed limits. Instruments are used to indicate the behavior of the engine and make successful plant operation and maintenance easier.

PERFORMANCE OF DIESEL ENGINES

In addition to knowing how diesel engines work and how they are constructed, you should also know how they perform and how they can be applied most effectively.

Thermal efficiency of any prime mover is related to its effectiveness to turn the heat in the fuel to useful shaft output and is expressed as the percentage of the total fuel energy converted to useful work. The diesel engine ranks high among other prime movers with a thermal efficiency of about 35 percent. The remaining 65 percent of the total heat in the fuel is dispersed within the engine in the following manner: Jacket loss is the heat absorbed from combustion zone by the water surrounding cooling jackets; Exhaust or radiation loss is the heat carried away in the hot exhaust gas and heat radiated from the engine and exhaust manifold; and Friction loss is caused by the friction of the crankshaft, connecting-rods, bearings and pistons and is disipated as heat, adding to the above named losses. The following tabulation is a typical heat balance for a diesel engine and a gas (otto cycle) engine;

	Diesel Engine	Gas Engine
Useful work	34%	25%
Jacket loss	30%	30%
Exhaust & radiation loss	27%	38%
Friction loss	9%	7%

Rating Standards of diesel engines are specified by the Diesel Engine Manufacturers Association (DEMA) and are based upon the operation of the engine at altitudes not to exceed 1500 feet and with atmospheric temperatures not in excess of 90 degrees Fahrenheit. The capacity of a diesel engine is effected by temperature and barometric pressure of the intake air and hence by the altitude at which the engine operates. Engines to operate at altitudes above 1500 feet or in excess of 90° Fahrenheit ambient temperatures are derated in accordance with curves published by DEMA. As an average the capacity of the engine is decreased about 3% for each 1000 feet or fraction thereof in excess of 1500 feet, and about 0.25 percent decrease in capacity for each degree Fahrenheit increase in excess of 90° Fahrenheit.

Fuel consumption of diesel engines using oil as a fuel is usually expressed in pounds of fuel per net brake horse power hour while operating at rated speed and using a reference fuel oil of 28 degree API gravity having a high heat value of 19,350 BTU per pound. Because natural gas fuels vary between 850-1250 BTU per cu. ft. in heating value, the fuel consumption of gas burning and dual-fuel engines are usually expressed in BTU per net horsepower hour.

Typical fuel-rate curves for diesel and gas (otto cycle) engines at full and partial loads are shown in figure 11. The fuel rate for a diesel engine varies slightly while operating between full and one-half loads. In general, large slow-speed engines show better fuel rates than small high-speed engines. Dual-fuel engines show fuel rates as good as or better than oil diesel engines.

Investment Costs of diesel plants vary from $150 to $300 per kw depending upon the type of building, number and size of engines, kind of cooling and many other design features. Large plants generally show the lowest unit costs.

Diesel engines are effectively used in a variety of applications in the generation of electric power in plants of industrial concerns, municipalities, utilities and cooperatives where the total plant capacity usually does not exceed 15,000 kilowatts. Such advantages as compactness and simplicity of installation, quick starting, and freedom from stand-by costs makes the diesel engine highly suited for stand-by and emergency power applications. Industrial applications of diesel engines are numerous. A large number of diesel engines directly drive such industrial machinery as, cotton gin, flour mills, refrigeration compressors for ice-making, pumps, and pipe line compressors. Here again, compactness and simplicity of installation, as well as purely economic considerations warrant their use. Current tendencies are towards the use of diesel engines of V-arranged cylinders, higher rotative speeds and with higher brake mean effective pressures.

I hope this brief narrative will provide the information which will make your next visit to a plant using internal combustion engines more interesting.

ACKNOWLEDGMENTS

I am indebted to the publishers of technical periodicals, the manufacturers of diesel engines and suppliers of related equipment for the technical data and illustrations used in the preparation of this paper:

Power, Diesel Progress, Diesel Power, The Cooper-Bessmer Corporation, Nordberg Manufacturing Company, Baldwin Lima Hamilton Corporation, General Motors Corporation, Fairbanks Morse & Company, Enterprise Engine & Foundry Company, National Supply Company, Standard Oil Company, Socony-Vacuum Oil Company and others.

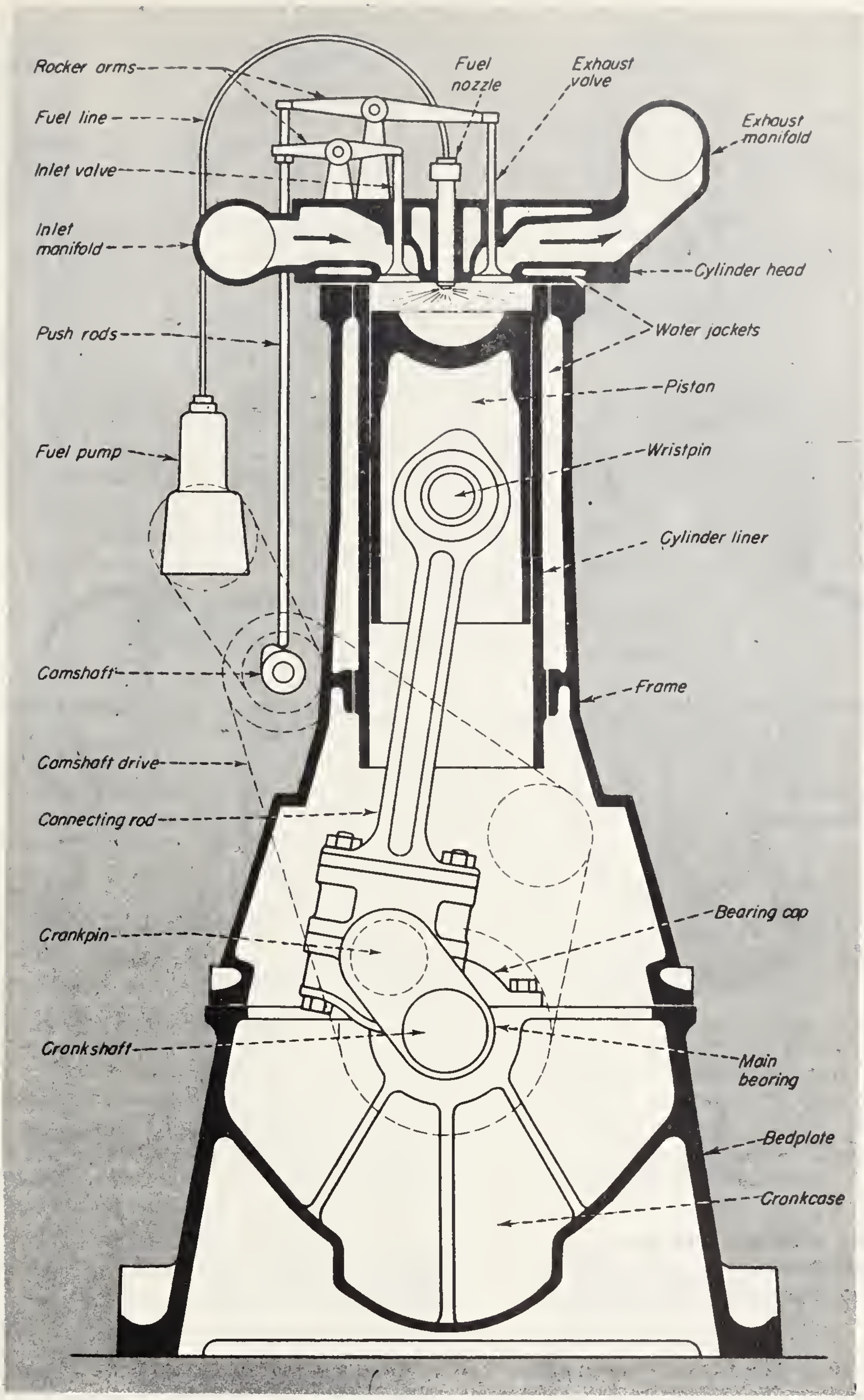
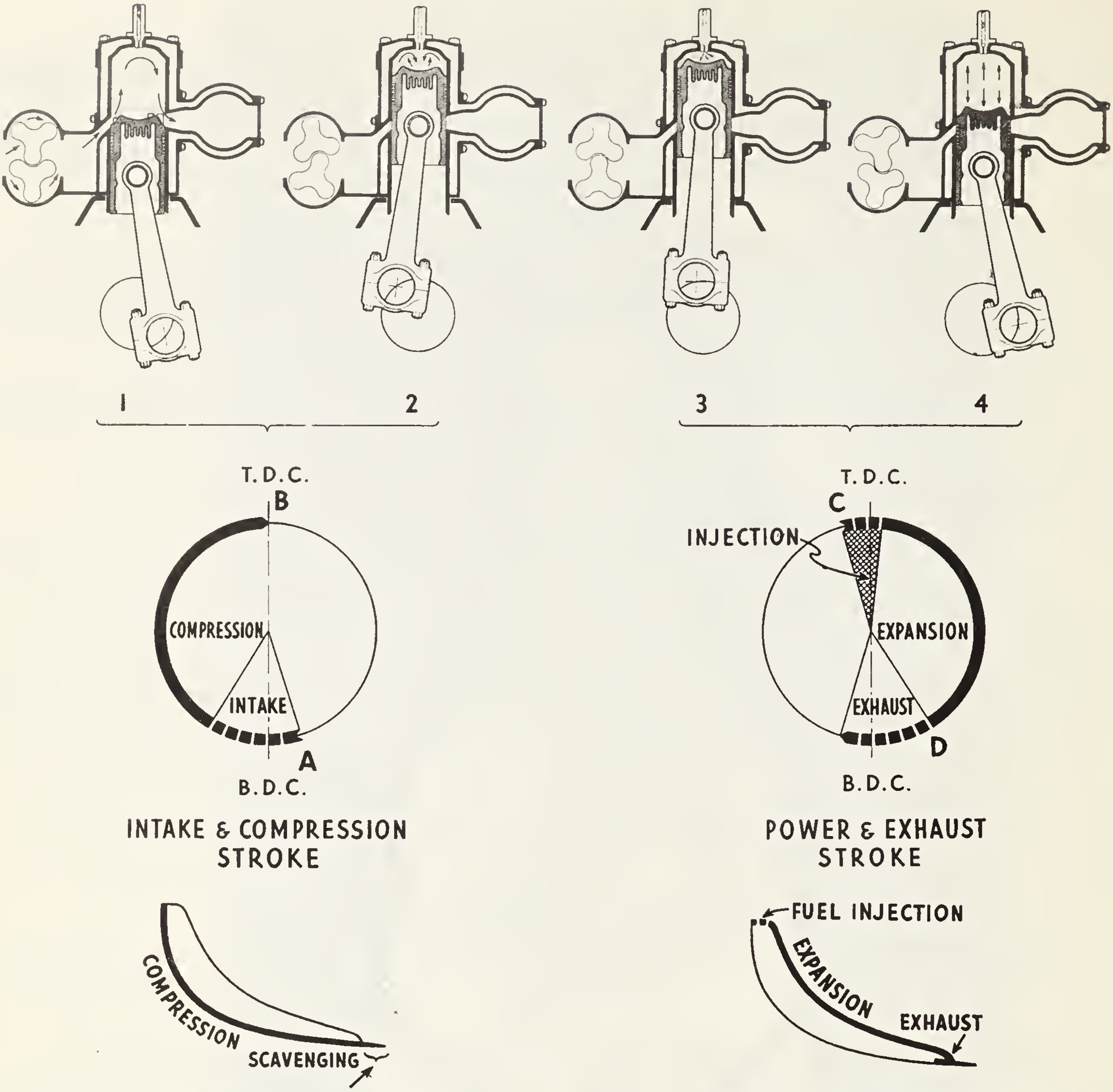


Fig. 1. Elements of an Internal Combustion Engine



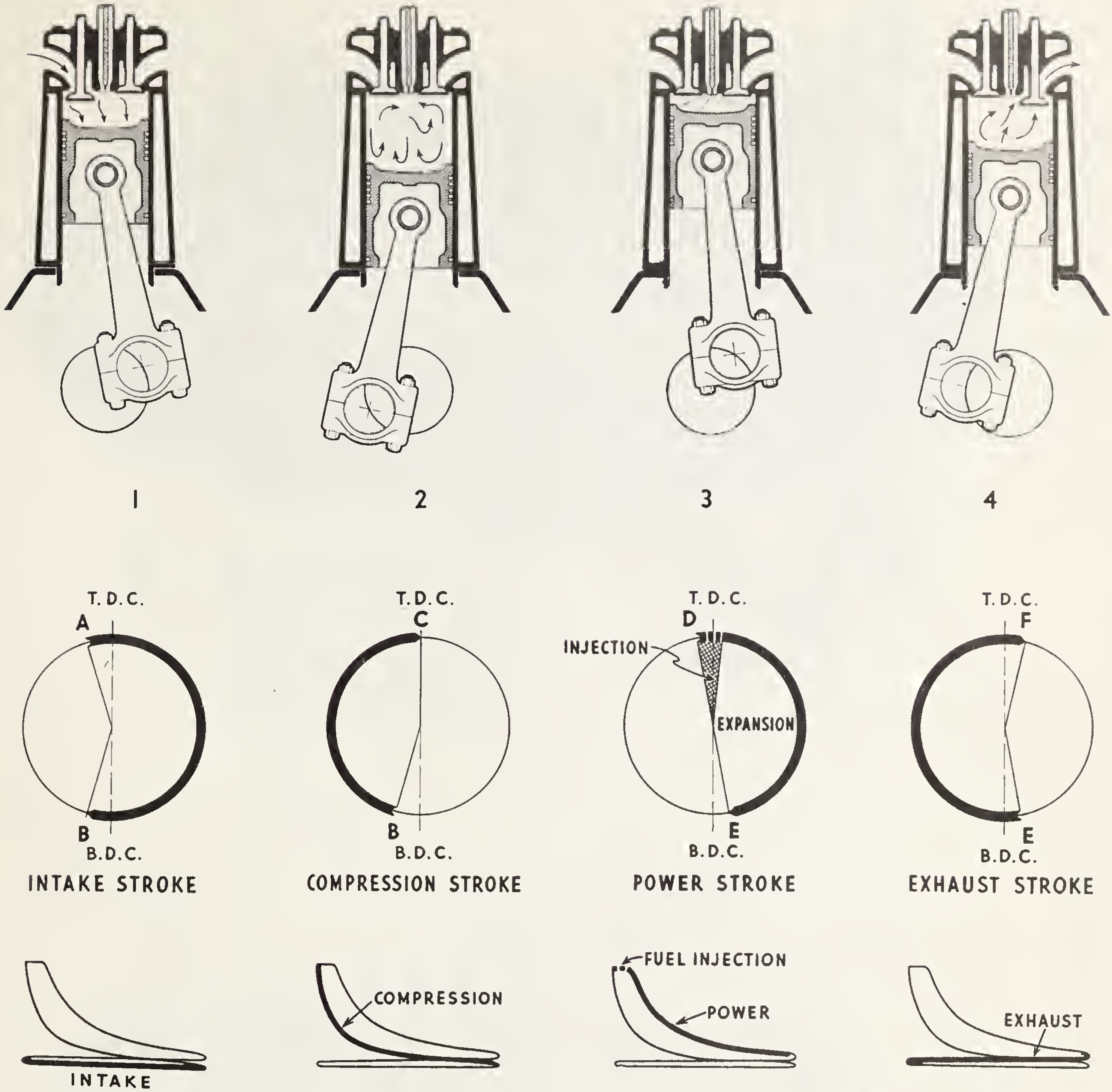
1. As inlet and exhaust ports are uncovered air is forced through the combustion space scavenging exhaust gases from the previous cycle and charging cylinder with air.

2. As piston moves upward it covers all ports and compresses the air charge.

3. Injection begins just before TDC; ignition takes place and burning continues as the piston moves downward.

4. Expansion of the burned fuel forces the piston downward through the power and exhaust stroke.

Fig. 2. Two Stroke Diesel Cycle



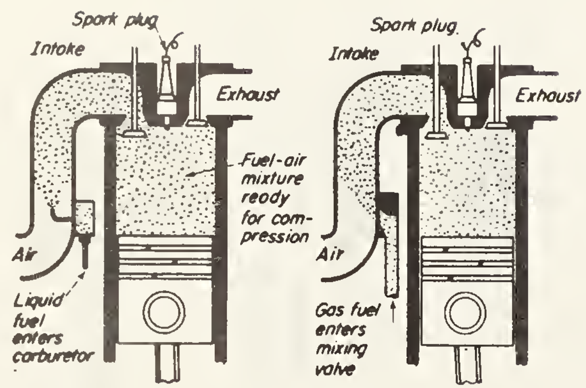
1. Air enters through inlet valve as the piston moves downward.

2. All valves are closed and air is compressed as the piston moves upward.

3. Fuel is injected, ignition occurs, and expanding gases force the piston downward.

4. Spent gases are exhausted as the piston moves upward.

Fig. 3. Four Stroke Diesel Cycle



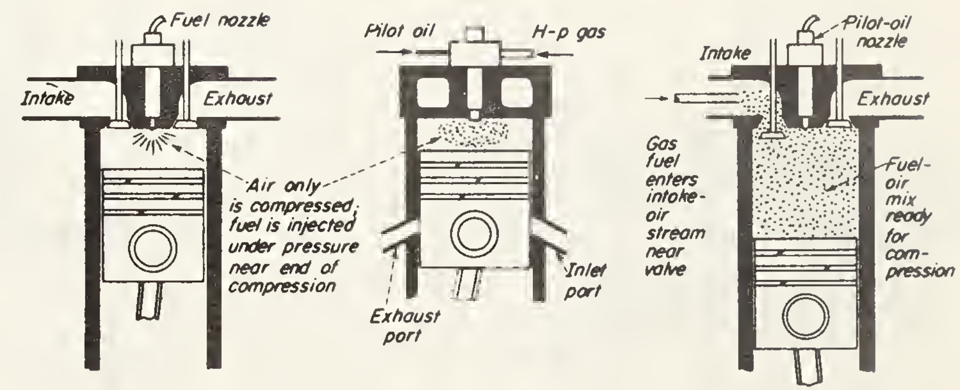
GASOLINE ENGINE

1. Carburetor vaporizes fuel and mixes it with air in proper proportions
2. Suction stroke, with inlet valve open, fills cylinder with mixture
3. Compression stroke raises mixture pressure to 100-225 psi
4. Spark ignites mixture near end of compression stroke
5. The fired mixture expands, pushing piston down
6. Exhaust valve opens; rising piston clears cylinder of burned gas

GAS ENGINE

1. Mixing valve blends air and gas fuel in proper proportions
2. Suction stroke, with intake valve open, fills cylinder with mixture
3. Compression stroke raises mixture pressure to 75-300 psi
4. Spark ignites mixture near end of compression stroke
5. The fired mixture expands, pushing piston down
6. Exhaust valve opens; rising piston clears cylinder of burned gas

Fig. 4. Otto Cycle Principle



DIESEL ENGINE

1. Suction stroke, with inlet valve open, fills cylinder with air
2. Compression stroke raises pressure to about 500 psi
3. Fuel injection starts at or near end of compression stroke
4. High air temperature, caused by compression, ignites fuel
5. Burning mixture expands, pushing piston down on "working" stroke
6. Exhaust valve opens; rising piston clears cylinder

GAS-DIESEL ENGINE

1. Air enters cylinder through inlet ports
2. Piston closes inlet and exhaust; compresses air to about 500 psi
3. Near end of compression, fuel gas and pilot oil are injected
4. Heat of compression ignites fuel; pilot oil stabilizes combustion
5. Burning mixture expands, pushing piston down
6. Near end of stroke, piston uncovers exhaust and inlet ports

DUAL-FUEL ENGINE

1. Inlet valve opens; suction stroke fills cylinder with air and gas
2. Compression stroke raises pressure of mixture to about 500 psi
3. Near end of compression, pilot oil is injected to initiate combustion
4. Heat of compression ignites pilot oil, which causes mixture to burn
5. Resulting expansion pushes piston down
6. Exhaust valve closes; rising piston clears cylinder

Fig. 5. Diesel Cycle Principle

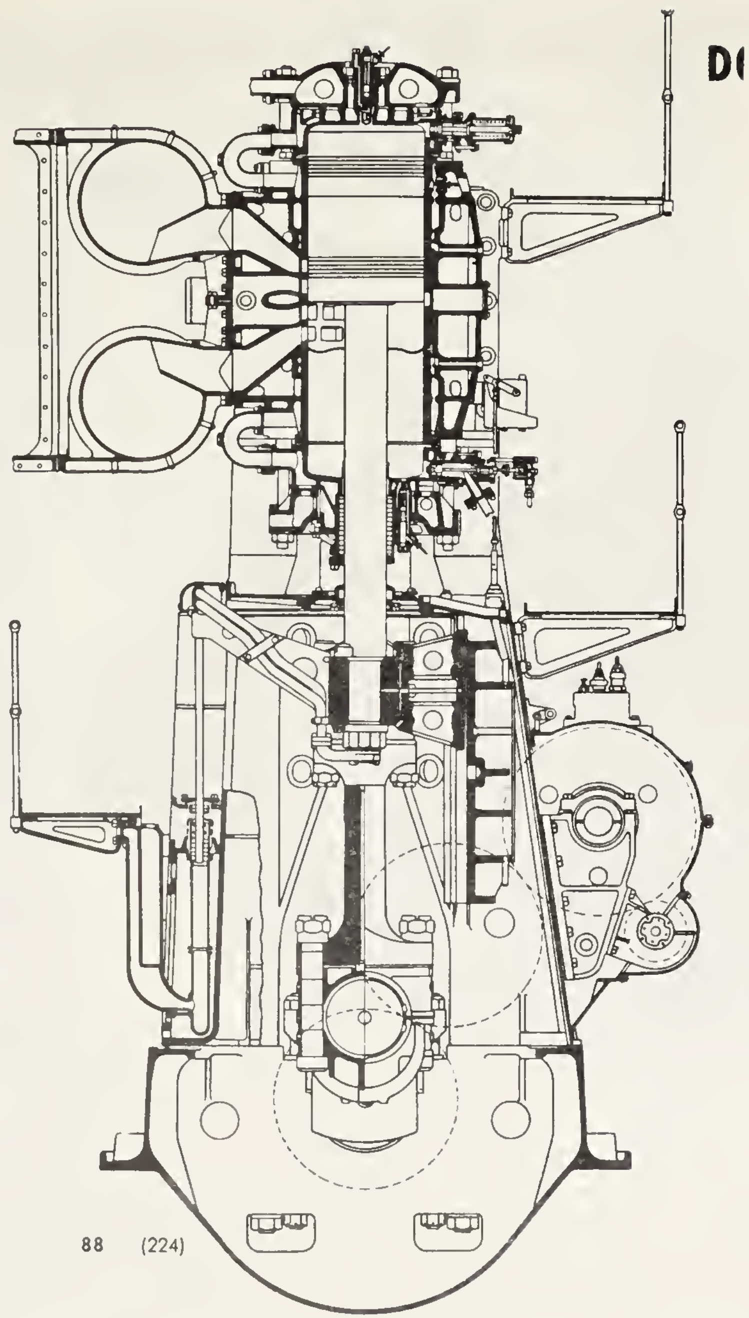


Fig. 6. Double Acting Engine

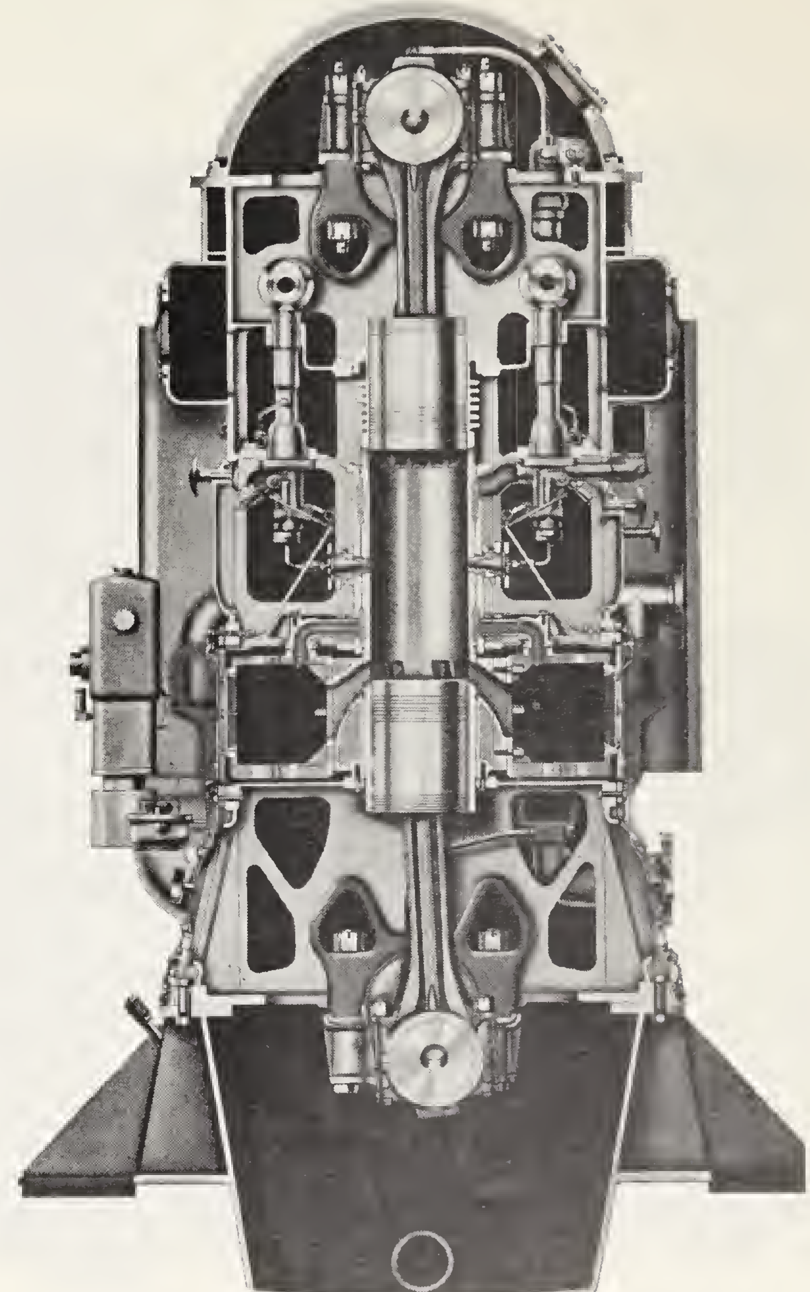


Fig. 7. Opposed Piston Engine

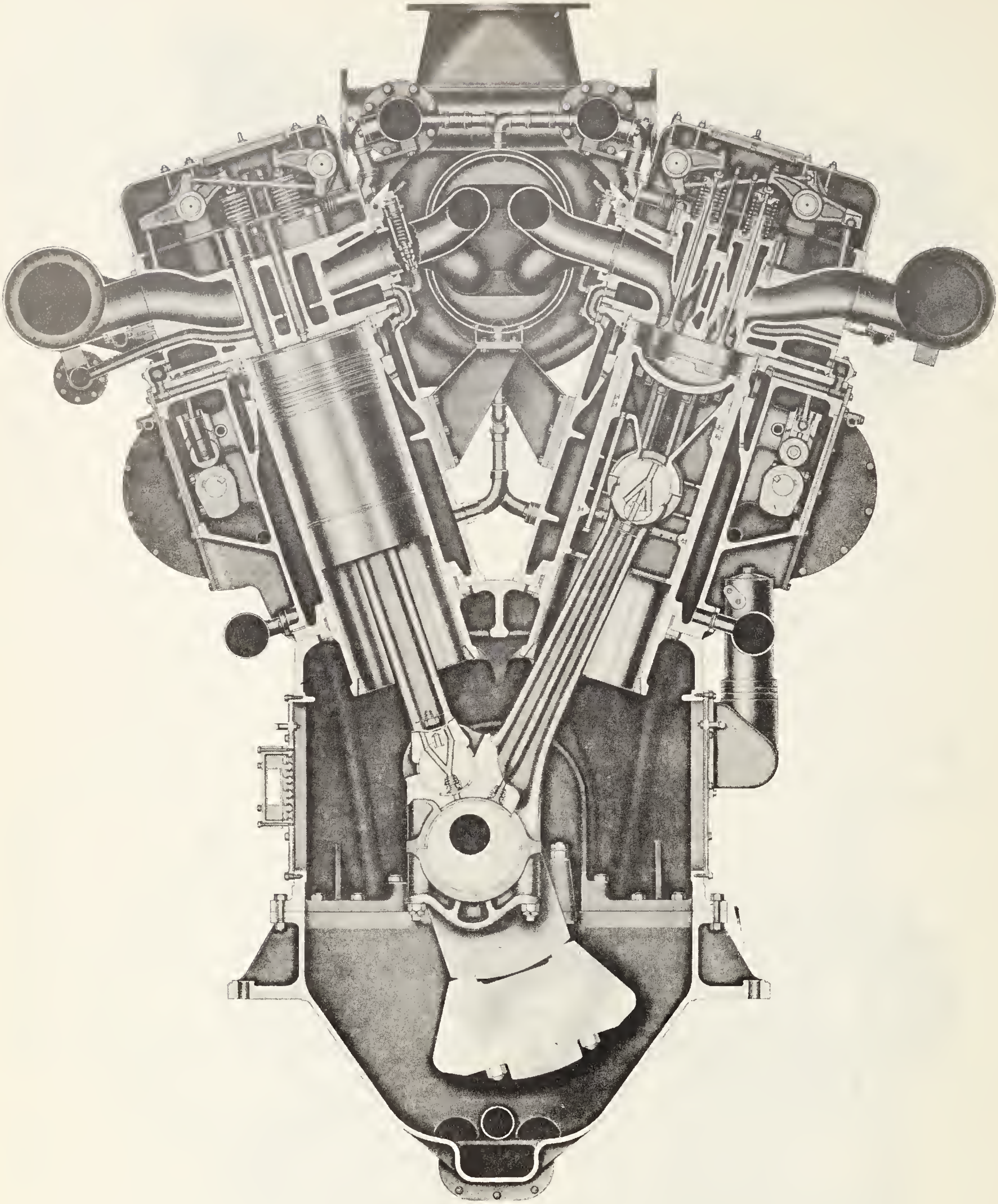
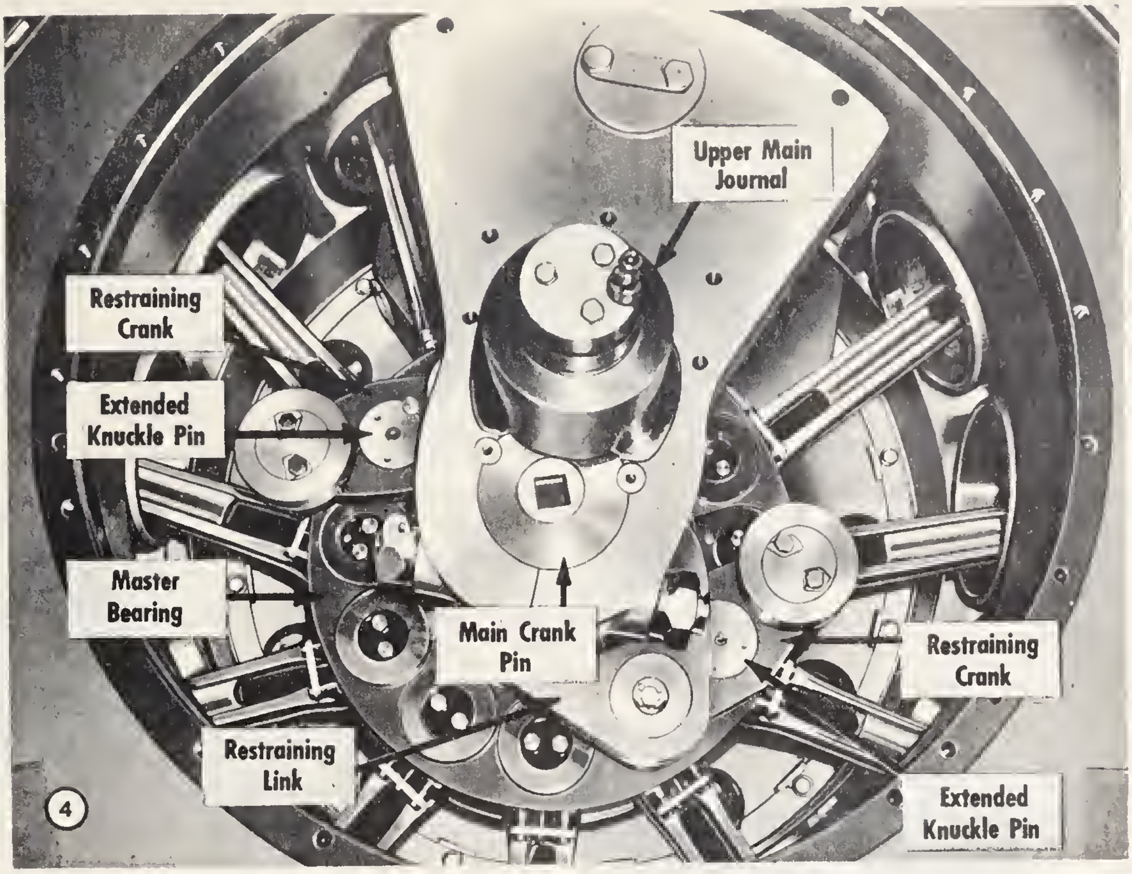


Fig. 8. V-Engines



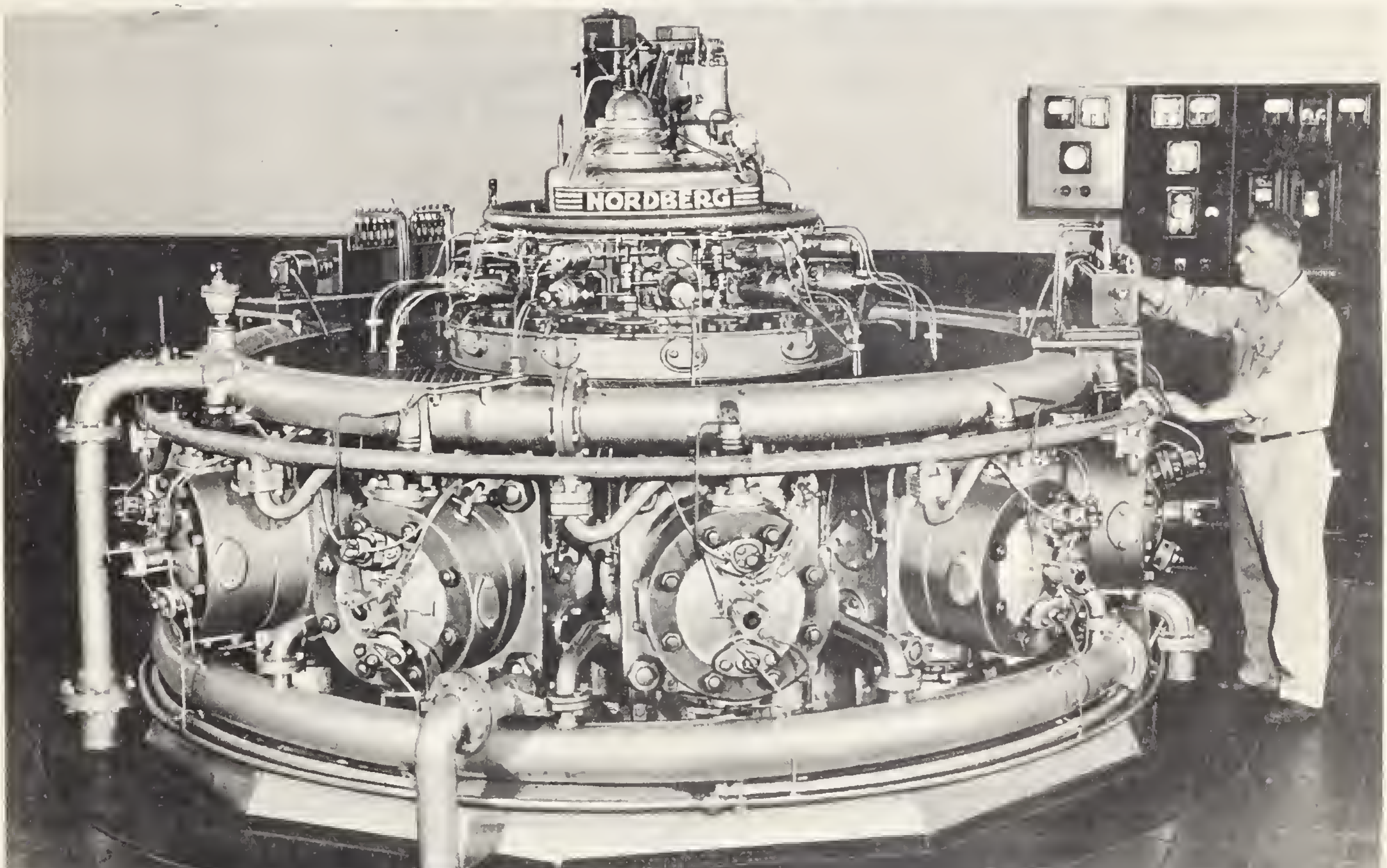


Fig. 9. Radial Engines

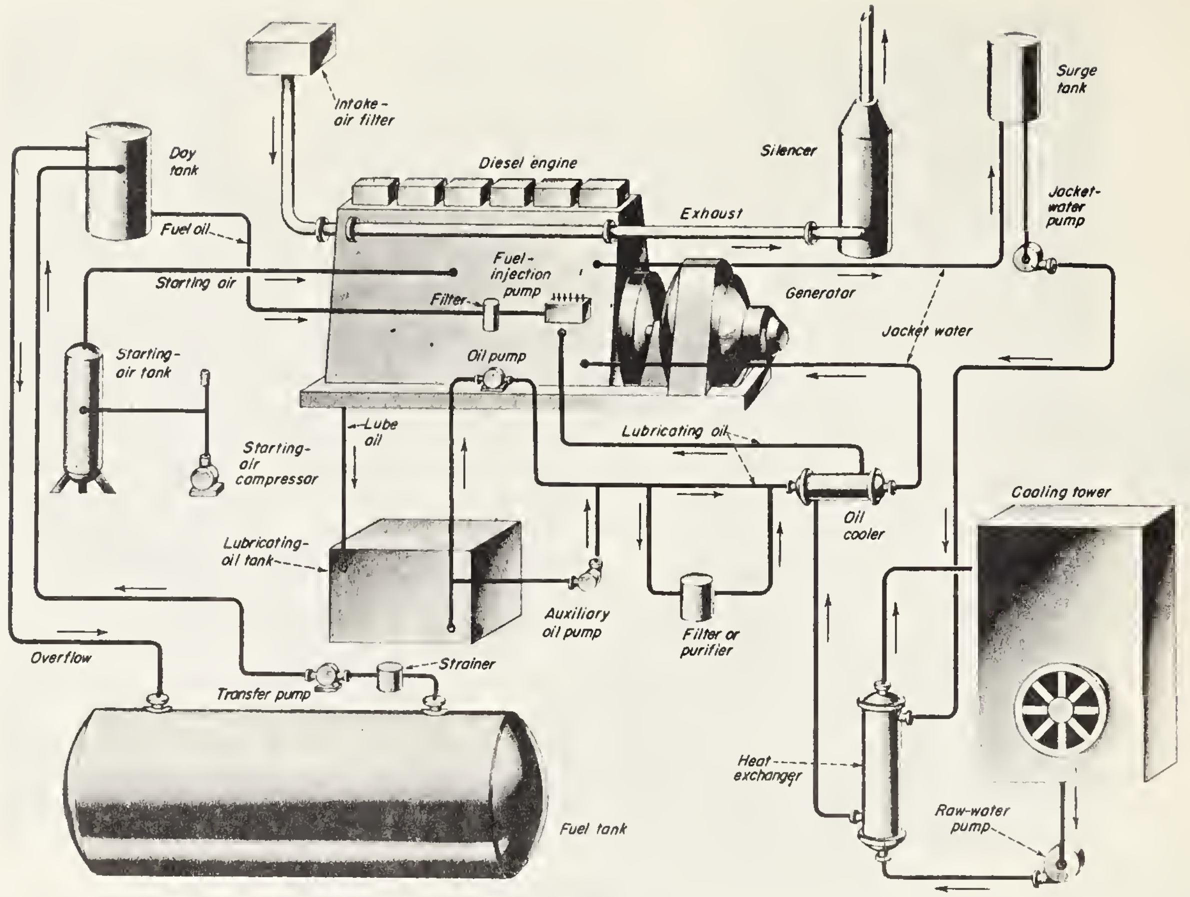


Fig. 10. Auxiliary Equipment in Typical Diesel Plant

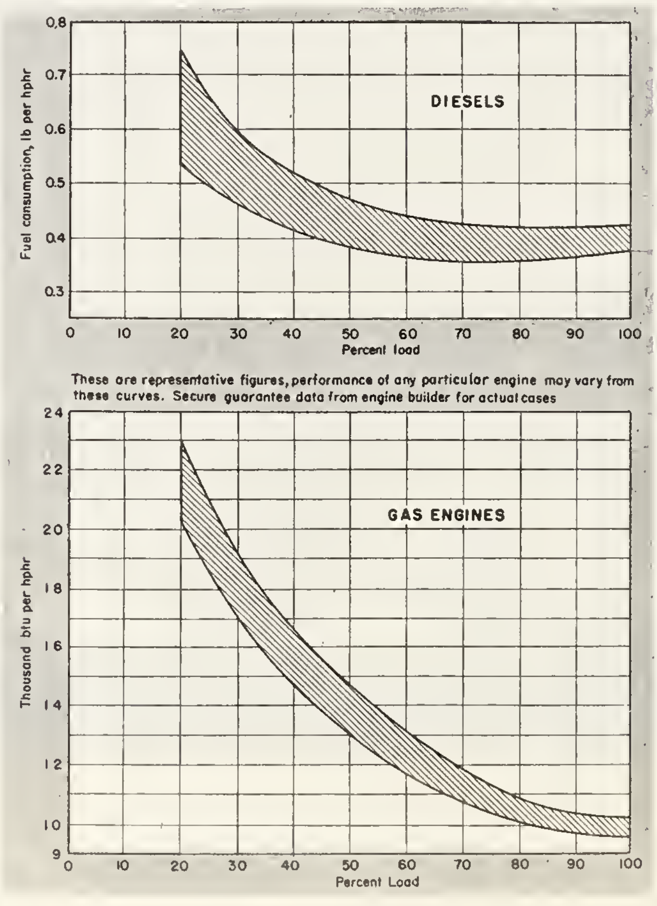


Fig. 11. Typical Fuel Rate Curves

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FUNCTIONS OF A PRE-LOAN ENGINEER

By Sam Shiozawa
Electric Engineering Division

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REA

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

FUNCTIONS OF A PRE-LOAN ENGINEER

Sam Shiozawa

The function of a preloan engineer as discussed in this paper will be directed toward planning activities related to serving rural type loads such as that served by REA-financed borrowers. In general discussion of preloan engineering functions covered herein will be channeled toward fulfilling engineering requirements of a loan application for generation and transmission facilities prior to its submission to REA. It is not the intent nor purpose of this paper to discuss REA loan policy requirements but to review from an engineering point of view planning activities related to the preparation of studies supporting a loan application. It should be kept in mind, however, that the final product of the preloan engineer is to plan a system which would accomplish two basic purposes:

(a) provide adequate service
(b) result in lowest costs

The term preloan engineer and planning engineer is used synonymously in this paper.

The work of the planning engineer is normally broad in scope. He might be referred to as a "broad brush" artist when compared to the design engineer. His job is one of looking at a project as a whole rather than a specific working part. The work tends away from detail but rather involves wide use of engineering judgment in the solution of a system power problem.

It has been stated that proper system planning involves among other things, the following W's — When, What, Where and Why. An attempt will be made to answer these questions in this paper.

BASIC CONSIDERATIONS

Preloan engineers are brought into the picture when the borrower is faced with some sort of power supply problem. This problem may take on many and varied aspects but is usually the result of load growth or the desire to obtain lower power costs. Load growth, of course, is a primarily problem of all electric utilities. It is an inherent characteristic of a healthy utility system. No system can remain static and survive. Proper planning must be done and carried out to meet the problem of load growth. It has become one of the major problems facing REA-financed borrowers today.

Load growth on REA system has been phenomenal. Such growth has often surpassed the highest estimates of planning engineers in the beginning of the program. In the early days systems were laid out on the basis of 80 to 100 kwh per member per month with anticipation that growth would never exceed this level. This consumption has risen to several time that level at the present time, with it not uncommon to find system being designed to serve load levels of 900 to 1000 kwh per member per month. The bar graph shown in Fig. 1 indicates a load growth since 1940 to fiscal year ending June 1954 of some 30 fold. The amount of generated power has increased from 8 percent of the yearly total energy to some 15 percent.

It is estimated that by 1963 the total consumption would be 27.5 billion kwhs and again be doubled to 45 billion kwhs by 1975. With such increases in loads future planning on REA systems will become increasingly important.

Symptoms of system overload are manifested in overheating of equipment, high losses, poor voltage and poor service. It is the planning engineer's job to prevent these ills.

In order to cover many of the aspects of system planning as related to generation and transmission facilities, it will be assumed that planning is to be done for a power system similar to an REA-financed power-type borrower. Such systems include a group of distribution borrowers being served through generation and/or transmission facilities owned by the group. Most of these systems have become quite complex operating utilities. Although generally small in comparison to the regular commercial electric utility systems, nonetheless, the power supply problems encountered are probably just as difficult. Originally many power cooperatives were served from single plants and transmission systems of a single voltage. But as the systems have grown these co-ops have made interconnections with outside suppliers both public and private, and have installed more and larger plants of different kinds of generation and constructed higher voltage transmission lines.

Upon review of the power supply problem, the preloan engineer is faced with the problems of what facilities, what method of power supply and what costs. He must make the selection here on the basis of the criteria of lowest cost and adequate service. The choice of facilities depends upon making an economic study of the combination that would most nearly fit the requirements.

On rural systems the matter of good service has become of prime importance. The success of the rural cooperative today has become one of not only providing service at reasonable cost but to provide so-called "metropolitan" service. Thus planning a system to assure this service to the members is of great importance to the power borrower and is something that should guide the planning engineer in his decisions.

A multiplicity of solutions may face the planning engineer and it would be his first step to eliminate all of those which could obviously be discarded. In general the possibilities can be reduced to a few possible plans and of these several would probably have to be studied in detail.

To make the final determination, annual cost studies must be made. These studies will be considered more fully later in the paper. The plans of service may include self-generation only, interconnections with outside suppliers for stand-by, integrated operations with outside suppliers, and various combinations of the above. Annual cost studies cover a period of years of operation including the expenses generally broken into the following categories:

(a) generation
(b) transmission
(c) general and administrative
(d) purchased power

Interconnections and Purchased Power Arrangements With Other Systems

As stated, most power-type cooperatives are rapidly developing into complex operating systems. More and more interconnections are being made with outside suppliers such

as private utilities, public power bodies, municipals and other power cooperatives. Such tendency for interconnections is true for the electrical industry as a whole.

One of the first solutions to the power supply problem which the planning engineer should consider is the advantages and desirabilities of obtaining power from other sources. Such arrangements may vary from simple interconnections for the interchange of peaking and stand-by capacity to complex ties for integration of system operations. Advantages of interconnection include:

1. Lowering of reserve capacity.

2. Load diversity between the systems.

3. Economies gained through energy and power interchange and sales.

4. Provision of maintenance stand-by without the addition of capital investment in generating facilities.

5. Staggered construction to fit load growth pattern.

The extent of the advantages to be gained through interconnections would, of course, vary with the individual case. It would be up to the preloan engineer to decide which type of interconnection would be most advantageous to the borrower.

Thus the preloan engineer is faced with the problem of not only selecting facilities, but rather a combination of facilities and interconnections. Perhaps the most difficult plan of service to work out is one involving connections with outside sources since negotiations are usually required before satisfactory arrangements can be worked out. The preloan engineer is often involved in such negotiations which means that a final plan of service cannot be presented until after agreements are reached.

It has been REA's procedure to require the borrower to clearly demonstrate that possibilities of obtaining working arrangements with outside suppliers have been thoroughly explored. The preloan engineering study submitted by the borrower should be fully documented as to this phase of the power supply situation.

Selection of Facilities

Should the solution to the power supply problem involve the choice of generation as well as transmission facilities, the planning engineer would be faced with the proper selection of these facilities. First will be considered the type of generation.

There is in service on REA systems the three types of generation--hydro, internal combustion and steam. A fourth type which holds great promise for the future is development of electric generation through use of nuclear energy. This is being followed closely by REA which has set up a working committee to keep abreast of developments.

Important to the consideration of selection of the type of generation include the following:

1. Loads to be served

2. Fuel availability and cost

3. Plant location

Another factor which would indirectly affect the choice of facilities is the problem of considering the possibilities of obtaining power from outside suppliers. This is an important aspect of proper planning and cannot be overlooked.

Hydro Capacity

The selection of hydro generation capacity is, of course, limited to areas where hydro power can be developed on a competitive basis. The amount of hydro power financed for service on REA systems is relatively small representing approximately 4.3 percent of the total REA-financed generating capacity in operation. Typically hydro plants show low production costs. Such costs average less than 4 mills per kwh for most REA plants. On the other hand one of the disadvantages usually encountered and which, in turn, partially explains why more hydro capacity has not been developed, is the high initial investment required.

The preloan engineer is often not in a position to study hydro site development as fully as might be required for loan purposes. In general a special study of the site in form of a preloan hydro site study is required. Independent hydro studies are needed since each site is a problem in itself. Of basic importance to any preloan engineering study is proper coordination of the hydro study in the over-all plan of service developed by the engineer.

Fuel Burning Plants

The determination as to whether steam generating capacity or internal combustion generating capacity should be installed usually depends on the size of the loads to be served, with cost of fuel and plant location also being important factors. Experience to date shows that for loads up to 10,000 kw or 15,000 kw internal combustion capacity has generally shown advantages and for larger loads steam generating capacity usually has showed up better.

One of the factors that should not be overlooked in any such determination is the matter of future fuel supply and available types of fuel in the area. On the basis of loads only the choice may be internal combustion; on the other hand a thorough review of the competitive fuel situation may result in the selection of steam.

Developments in the industry of equipment for burning various types of fuel have made both the steam and internal combustion generating plants more versatile. Steam plants can burn most types of fuel through use of proper furnace equipment. Coal, natural gas, oil and lignite are being used in REA plants. The Diesel industry has recently perfected equipment whereby internal combustion engines can be adapted to burn so-called Bunker "C" and other residual fuels. 3,4 Experience of one REA borrower with this feature in operation has shown savings of some 3.1 mills per kwh over use of regular fuel.

Diesel generating plants are characterized by inherently high fuel efficiencies, flexibility of operation, and relatively small amount of stand-by capacity being required. Internal combustion plants have found greatest application in service for individual distribution borrowers. The largest size unit normally installed at the present time is about 2500 kw. The trend, however, appears to be toward larger unit sizes. Recently funds were approved for the installation of 4000 kw class units in an existing REA plant in New Mexico. More manufacturers are making the larger unit

sizes today, such that bigger units will undoubtedly be available in the future on the same competitive basis as the 2500 kw units are today.

The total installed and operating internal combustion capacity financed by REA is approximately 290,000 kw. This represents about 32 percent of the total generating capacity financed by REA. 5, 6 Figs 2 and 3 show respectively the average cost per installed kw and fuel rates of REA Internal Combustion plants.

Another important factor in the selection of the type of plant is consideration of the life of the equipment. REA experience has shown that where proper care and maintenance has been given to a generating plant containing IC engines, that these continue to give good, reliable service at reasonable cost over long periods of time. The fact that loads increase on the system should not rule out the use of smaller IC units in production of energy; however, the life of such units are often shortened by improper maintenance under circumstances where the units are made obsolete because of load growth.

Steam generating capacity has become relatively more prevalent and important on REA systems in recent years. Practically no steam generation existed prior to 1941 to some 63.5 percent of the total capacity in operation financed by REA today. The total capacity in operation is approximately 571,000 kw. 5, 6 Figs 4 and 5 show respectively the average cost per nameplate kw and heat rates of REA steam plants.

As with IC capacity steam units are also going to larger sizes. Higher temperatures and pressures are also being used. The first steam unit financed by REA was a 3000 kw unit operating at 650 psi and 825° F. Today loan funds to finance a 50,000 kw reheat steam generating unit operating at 1450 psi and 1000/1000° F, and a 66,000 kw unit, 1250 psi, 950° F, have been approved. Undoubtedly larger unit sizes will be used in the future.

Another development in the electric industry is the trend toward standardization of steam generating units of the sizes normally installed in REA plants. Such standardization cuts down on the time of construction and simplifies the design of the plant. At the present time specifications for the AIEE-ASME preferred standard units have been completed for the 12,650 kw; 16,500 kw; 22,000 kw; 30,000 kw and the 44,000 kw units. Specifications for the 66,000 kw unit are now being written and consideration being given to a 100,000 kw unit.

One of the problems encountered in the selection of what generating facilities is the question of reserves. Not only must the anticipated loads be met, but how to do this at the lowest cost must be determined. REA practice has been in most instances to provide sufficient reserve to meet the loads on a firm basis. That is sufficient capacity being available in the plant to meet the maximum loads with the largest unit down. This can be accomplished by adding sufficient generating capacity for an isolated system, or to interconnect the system with some outside source. With interconnections a different approach can be taken regarding the size of the unit, in the direction of installing larger sizes. For greatest economy the amount of reserve should be kept to a minimum and where possible units should be added at the time when they can be economically loaded. Herein lies the advantages of the interconnected system as far as system reserves are concerned in that larger and more economical units can be installed as well as making it possible to achieve the greater economy of operation.

On REA systems where loan funds at a relatively low interest is available the

planning engineer would be wise to consider equipment having features which produce greater economy. With the lower rate of interest the borrower can afford to invest in such auxiliary equipment to affect greater economy of operation.

Transmission

A review of voltage levels used on REA systems show a steady rise. In the beginning the highest voltage used was the familiar 7.2/12.5 kv on distribution systems. As the loads increased, transmission voltages appeared beginning with 22 kv, then 33 kv, 44 kv, 66 kv, 138 kv and the highest today of 161 kv. On power-type systems the 69 kv transmission system is fairly standard. 138 kv and 161 kv backbone lines are becoming more prevalent. In 1948, only 10.8 percent of the miles of transmission line in operation on power type borrowers was of the 69 kv level with no lines above this voltage. By 1953, 60.2 percent was of the 69 kv and some 5.3 percent being 115 kv and above.

The planning engineer is faced with the problem when laying out the transmission system of not only selecting the proper voltage level but also the degree of reliability of service that should be built into the system. Fortunately he has the network analyzer to help him design the system. However, he must still decide the routing, location of substations, wire size, loop feeds, and other aspects which affect economics and service of the system. One of the factors which should be considered is the predominate voltage of the existing lines in the area, especially if interconnections are contemplated. On the other hand the voltage level should be high enough to meet the anticipated loads and to give reliable service. Often existing lines in the area are not adequate and consequently are a contributing factor toward the creation of a new transmission system.

In connection with transmission systems it has been REA practice generally to design systems to serve the anticipated loads of 10 or 15 years ahead. The provision of sufficient transmission capacity to meet such loads allows enough leeway so that expensive heavying up can be avoided soon after the system goes into operation as well as allowing the borrower time to get the system into operation on a sound basis before being faced with a load growth problem. A factor to be considered along with the voltage level on a system that should be weighed carefully is the balancing of losses in the system because of a certain voltage level as against economic gain in later years. Often on REA systems lower voltage transmission lines have become obsolete because of overload yet this does not necessarily mean that the borrower is worse off because a lower voltage was selected in the first place. The economic gain through lower investments and lower losses during the early period as against starting with a higher voltage with higher investments in the beginning should be studied.

It has been the experience of the industry, however, that too often when a voltage level should have been increased this change has not been made soon enough.

The transmission system must be able to deliver voltages to the distribution substations of such quality that the electrical equipment on the member lines will operate properly. Good transmission voltage regulation should be within the range of approximately 95 to 105 percent of that at the source. REA practice has been to design systems such that energy can be delivered at proper voltage levels to the member substations without the use of reactive equipment. This allows sufficient capacity in the facilities to take care of unforeseen load growth.

Power Cost Studies

The test of whether the final plan meets the basic requirements of adequate service and lowest cost is a study to determine its economic worth. This answers the question of why, one of the factors of proper planning. The planning engineer must determine why the plan selected is the best one. As previously stated, annual cost studies are made to determine the best plan of service.

In the review of loan applications by REA staff engineers for generating and transmission facilities power cost studies are made to determine the annual costs of the plan of service in question. These studies are made covering yearly costs for a 10-year period and the costs for this period are totalled. The period considered coincides with the 10 year period of the power requirement studies made for the borrower submitting the application. It is felt that the determination of the optimum plan should be made within this comparatively short period of time if the advantages of future technological developments are not to be lost.

As stated previously, annual or power cost studies include yearly expenses connected with the following:

(a) Generation

(b) Transmission

(c) General and Administrative

(d) Purchased Power

The above list of annual costs include operating and fixed costs for each. For studies made by REA operating expenses are based on experience of existing plants. When making economic comparisons for the 10 year period an interest and depreciation factor is used to reflect the costs as they will appear on the cooperative's books. It is REA's practice to use this as a basis of comparison over a 10 year period of operation to determine whether a particular plan demonstrates economic advantages over another.

Yearly depreciation rates used in such studies are shown below:

Transmission Plant	2.75%
Steam Production Plant	2.52%
Internal Combustion Plant (slow speed)	3.00%
Internal Combustion Plant (high speed)	7.00%
Hydro Plant, Individual Study, Generally	2.00%

The above rates are composites.

The working out of the details in an annual cost study may become very complex and often involves judgment where details are not available. One of the problems that

may be worthy of some comment is that of determining loading of various sources that may be available to serve a system. For purposes of the power cost study made by REA a set of load duration curves have been developed. A copy of the curve is shown in figure 2. These curves based on rural loads of the type served by REA are of value in making this determination. Basically, the use of the curve when determining energy production of various sources is one of base loading the most economical source first and to add other sources on top of the base units until the load is served. A determination of the amount of energy supplied, amount of time the unit would be in operation, etc. can be made. Such information is important for the proper allocation of energy produced and costs among the sources. It is not uncommon to find the three different types of generation mixed with a combination of purchased power sources. With such systems the selection of the combination of sources and the loading on each to produce the lowest cost becomes one of the major problems of a power cost study.

Conclusions

The function of the preloan engineer is primarily one of system planning. His duties include the broad consideration of all phases of proper planning as they relate to the needs of the REA-financed power systems. The problem that he is faced with is primarily one of meeting the problem of system load growth which has been very rapid on REA systems since the beginning of the program.

The solution of the problem must result in providing adequate service at the lowest cost to the borrower.

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6. REA-Financed Generating Plants (Operating or Active Stand-by) Operations and Maintenance, Power Generation Branch, Electric Engineering Division, Rural Electrification, U. S. Department of Agriculture, January 1954.

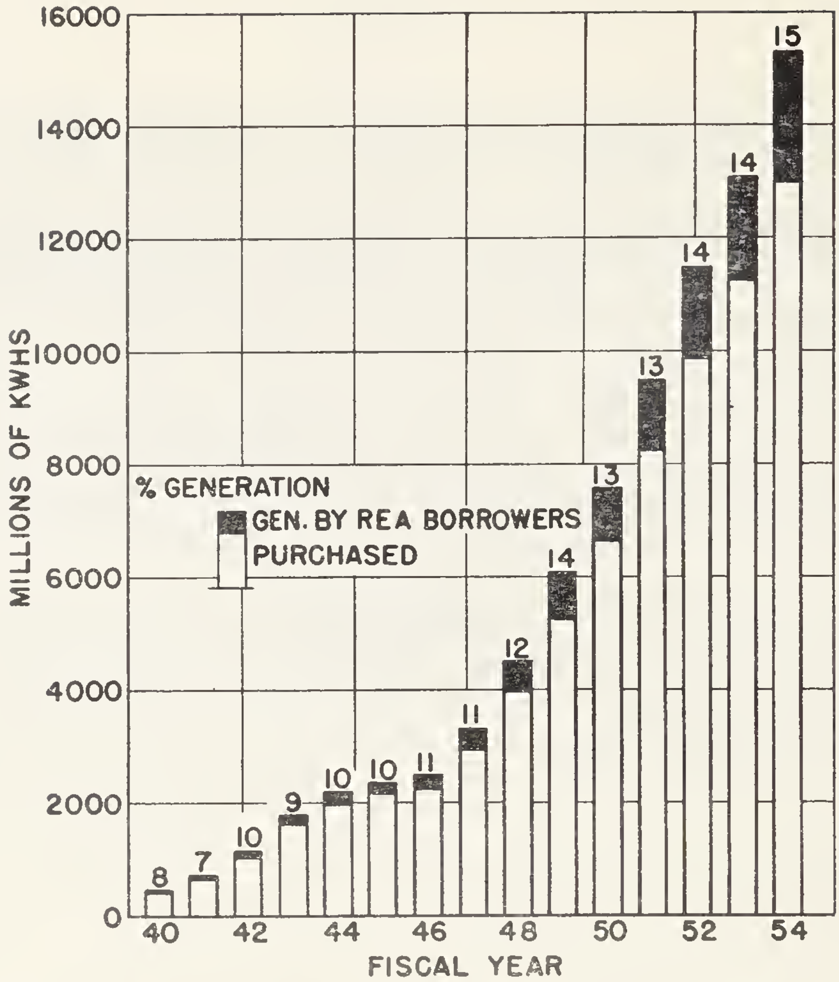

Fig. 1. Energy Generated and Purchased by REA Borrowers

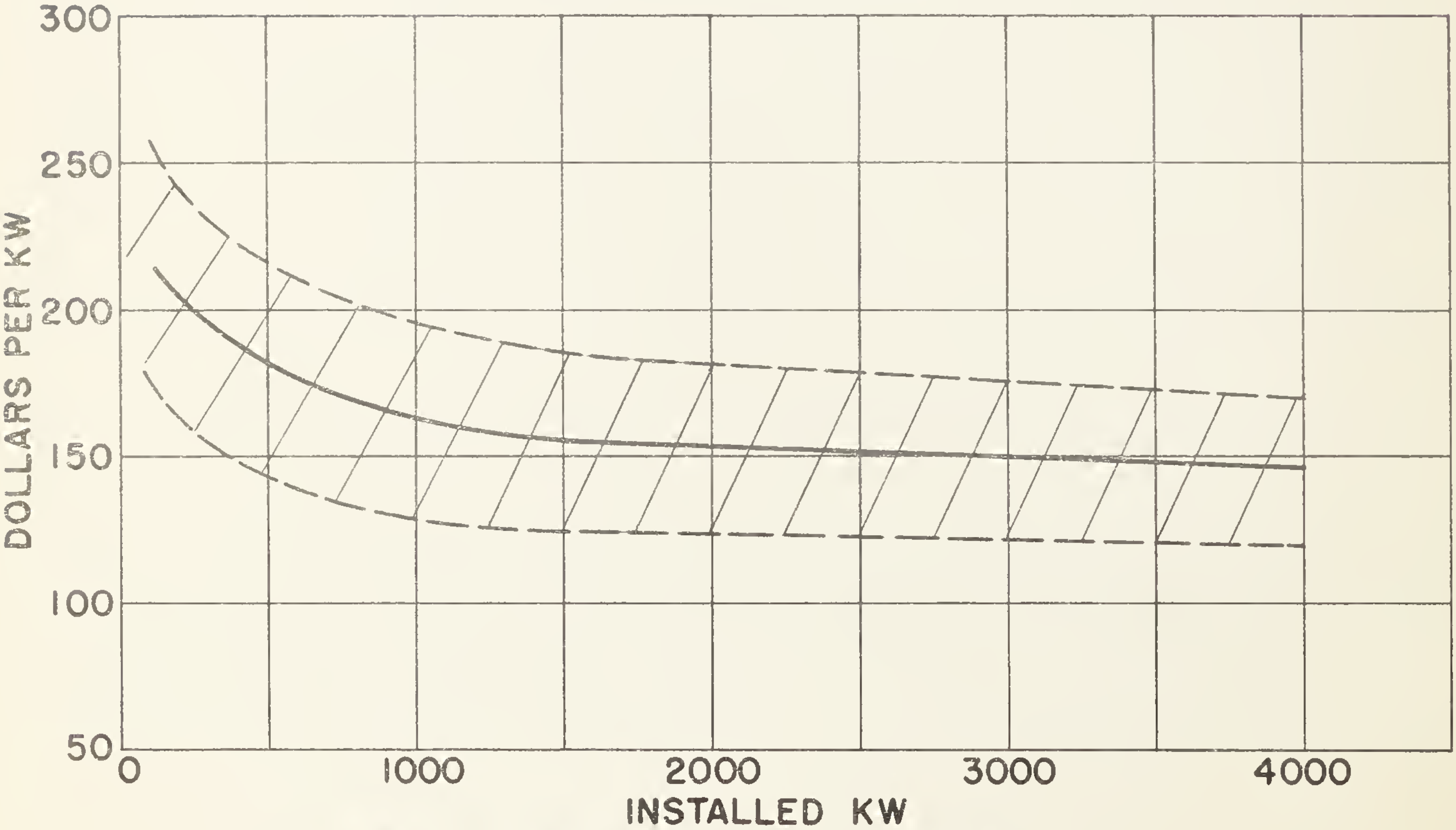

Fig. 2. Average Total Cost per kw Internal Combustion Plants

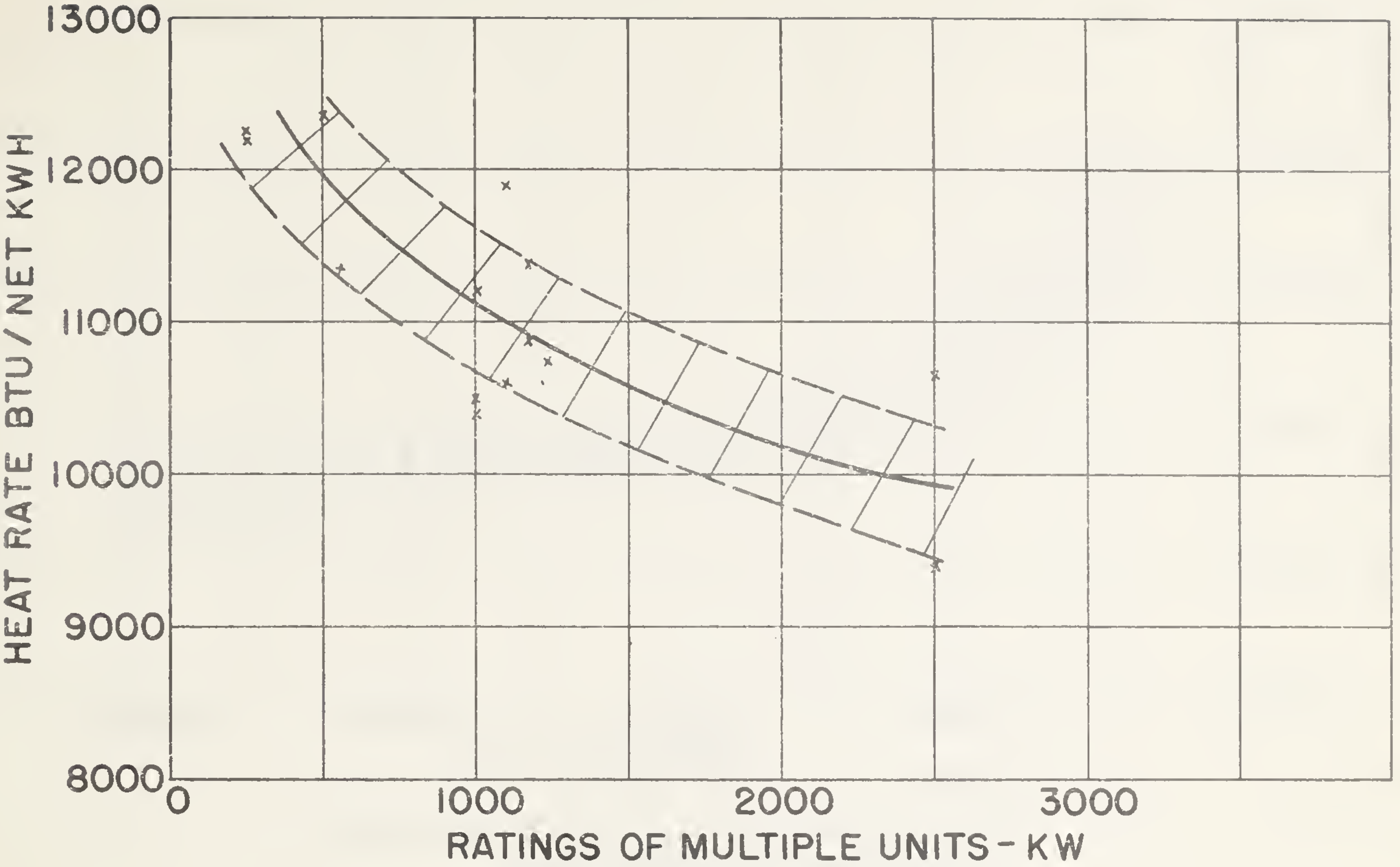

Fig. 3. Average Net Heat Rate of REA-Financed Internal Combustion Plants Using Multiple Units of Various Ratings

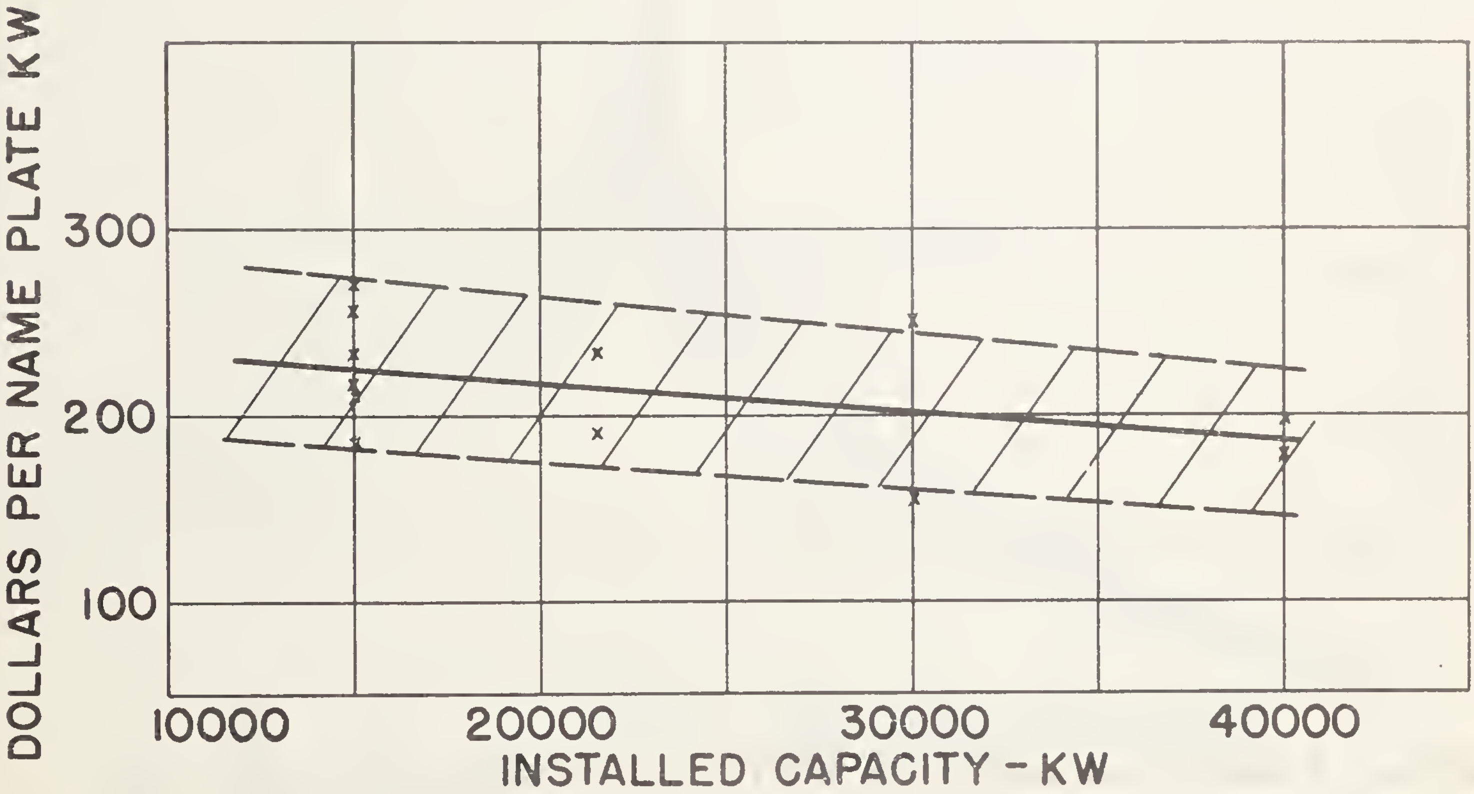

Fig. 4. Average Total Cost per Name-plate kw REA-Financed Steam Plants

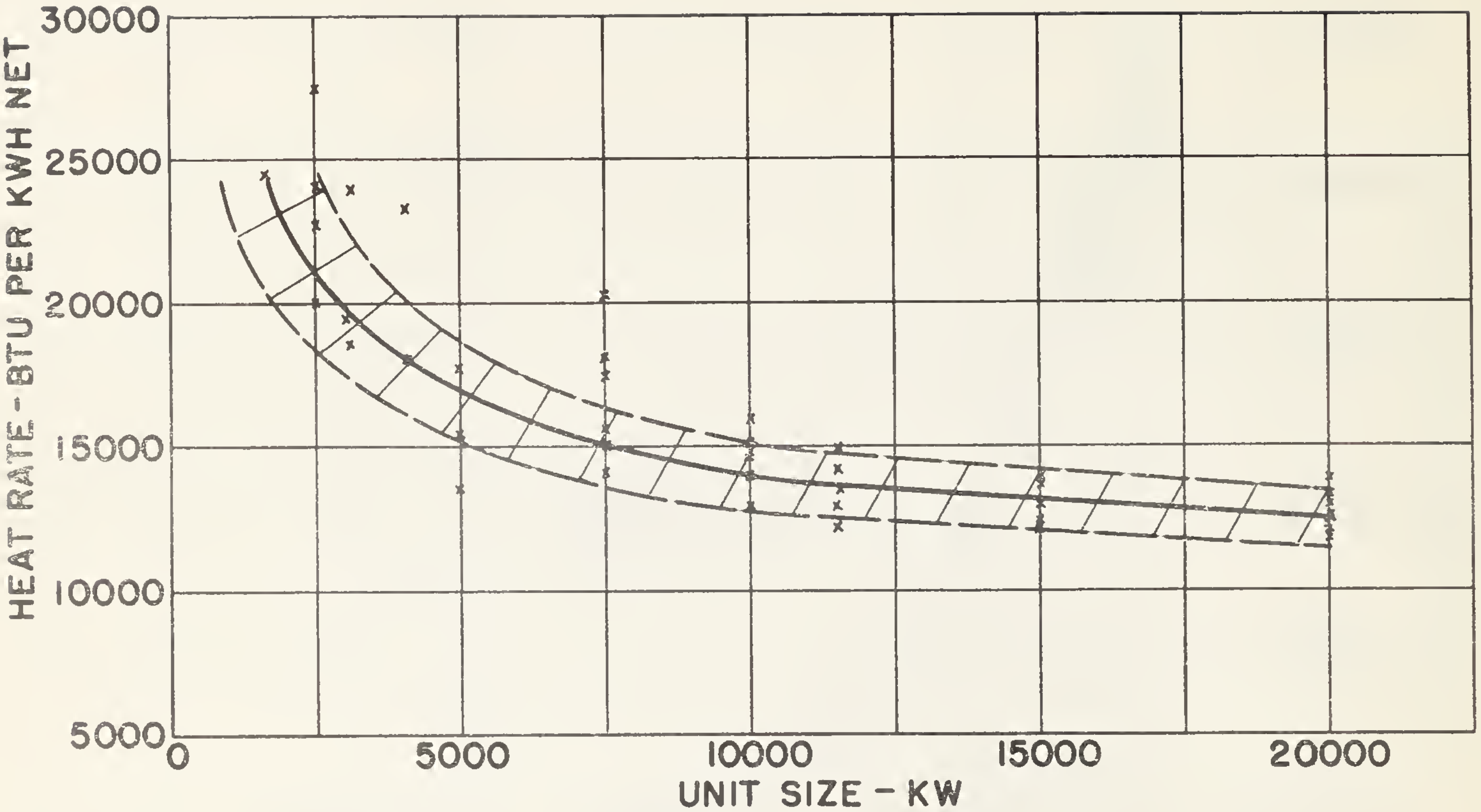

Fig. 5. Average Annual Net Heat Rates of REA-Financed Steam Plants

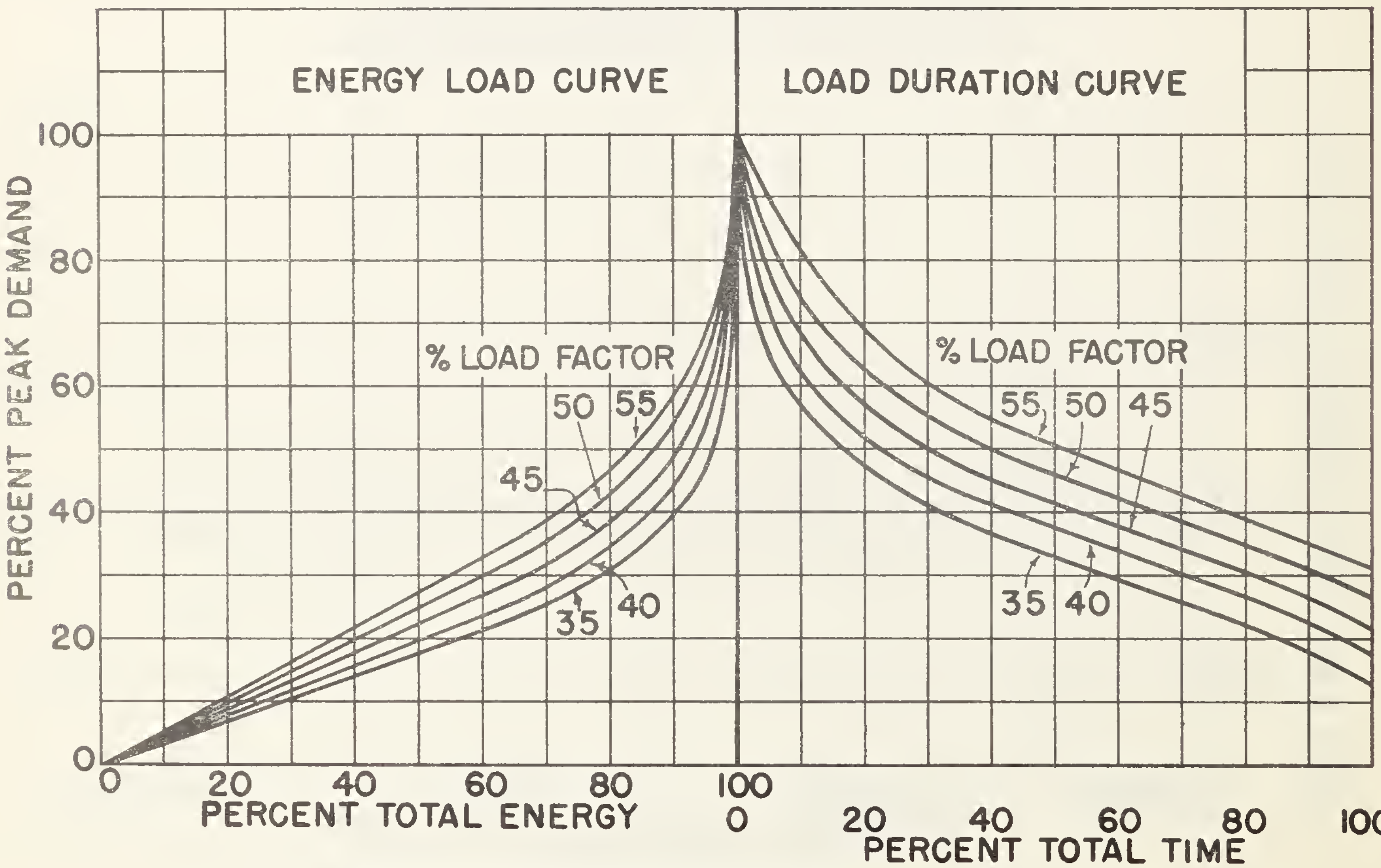

Fig. 6. Energy Load and Load Duration Curves

OPERATION AND MAINTENANCE OF

ELECTRIC GENERATING PLANTS

By W. E. Rushlow

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
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RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

OPERATION AND MAINTENANCE OF ELECTRIC GENERATING PLANTS

W. E. Rushlow

The subject of operation and maintenance is so broad it is difficult to know where to begin. Even the term "Operation and Maintenance" is difficult to define. The dictionary defines "operation" as exerting a power in order to bring about some end or purpose and "maintenance" as to hold or keep in any condition, especially efficient. The end or purpose in the operation and maintenance of generating plants is the generating plant's part of providing adequate, reliable, low-cost power. This paper will deal with how the operation and maintenance of generating plants affect the system and how the system affects the operation and maintenance of generating plants. Averages and generalities will be used and many of the statements when applied to individual cases will not be true. The purpose of the paper is to point out some of the basic considerations of operation and maintenance of generating plants and how the operation and maintenance of generating plants affects the end or purpose of obtaining adequate, reliable, low-cost power.

What is considered as adequate, reliable, low-cost power is determined by pre-loan studies and other reviews previous to making a loan. In arriving at the cost of power delivered to the low side of the distribution substation, the generating plant production expenses are by far the greatest single annual cost item and often as great as all other annual costs combined. For systems having fuel burning plants only the fuel costs alone amount to 30 or 40 percent of the total cost of power delivered to the low side of the distribution substation. Fig. 1 shows the disposition of 1952 revenue dollar for an REA G&T cooperative. Whether power is purchased from someone else or whether it is self-generated, these costs are present.

GENERATING PLANT COSTS

General

Of the cost of power delivered to the low side of the distribution substation what is contained in the portion of the cost of power delivered to the generating station bus? There are "Expense Items" and "Overhead Costs." Both are common to all generating plants but vary considerably for different types of plants, sizes, type of fuel (if any), location, plant use, construction costs and other factors. For steam and internal combustion plants the expense items greatly exceed the overhead costs. For hydro plants the opposite is true.

Expense Items

Expense items are broken down into labor (operation, maintenance, supervision and engineering), fuel, operating supplies and expenses, and maintenance material. These items are subject to variations in day to day activities and in most cases will vary directly with the use of the plant. They are known as a plant's "Production Expenses" but are sometimes referred to as operation and maintenance expenses or costs. These expenses are frequently shown in statistics and are a valuable source of information to the operating engineer as they deal with items over which some control may be exercised after a plant is built.

Overhead Costs

Overhead costs include depreciation, taxes, interest, insurance, administrative and general. These items, although called overhead costs, are frequently referred to as "fixed charges" as little or nothing can be done about the actual dollar costs

once a plant is built. Overhead costs are determined by the types of plant and construction costs and are of minor interest to the operation and maintenance engineer. The two items "Production Expenses" and "Overhead Costs" make up the "Total Production Cost" or the cost of power delivered to the bus bar of the generating plant.

PRODUCTION EXPENSE DETAILS

General

As no fuel is used in hydro plants the greatest item of production expense is eliminated. Hydro plants usually have fewer units and fewer auxiliaries. The prime mover is simpler and more rugged in design; has fewer moving parts and is subject to less strain due to heat and pressure. Little can be done to change efficiency for a given flow of water. Labor, maintenance material and operating supplies are therefore less than for an equivalent sized steam or internal combustion plant. A hydro plant is particularly adaptable to automatic and semi-automatic operation further reducing labor costs. Additional hydro expenses incurred in the maintenance of reservoirs, dams, gates, sluiceways, etc., are more than offset by other savings so that the total production expenses for hydro plants are considerably less than for steam or internal combustion plants even though fuel costs are not considered. Unfortunately, unless geographical conditions are right or large investments per kw are made, a hydro plant does not have the flexibility of steam or internal combustion plants and the low production expenses cannot always be made to fit the purpose of generating adequate, reliable, low-cost power. In general, REA-financed hydro plants supplement purchased or self-generated power.

Labor

Questions often arise as to the necessity for so much labor in a generating plant. For a two-unit steam plant there will generally be four divisions of personnel; (1) supervisory and office force, (2) operating force, (3) maintenance force, and (4) coal and ash handling force. The total is seldom less than 20 and may run as high as 40, depending upon type of fuel, plant layout, and whether the plant is a base load plant or whether it operates on the system load curve with many stops and starts.

The operating personnel will be the largest division both in numbers and payroll dollars, for all job classifications require a minimum of four men to cover 24-hour, 365-day service. The other divisions normally require only one shift coverage and it is generally more economical to pay overtime occasionally than to carry more men on the regular payroll. Within the operating group we find switchboard, turbine, boiler and auxiliary operators. The first two jobs are sometimes combined, while the boiler operator is frequently provided a helper. Few plants operate with less than three men on a shift.

In many plants a shift engineer (who may or may not be on the supervisory payroll) is provided. When this is done in plants with small units, he generally has assigned operating duties. In plants with larger units and larger operating crews, he is likely to have supervisory duties only.

In different plants the same jobs may have different titles, and the same titles may be assigned to different jobs. For example, the titles Plant Superintendent, Power Production Manager, Chief Engineer, Chief Operator, and Plant Engineer are all in use for the same position in different plants - namely, the man who holds direct responsibility for the generating plant. Similarly, the title Chief Engineer may be the man who, in other plants is called Assistant Superintendent. Each plant bases job titles on some line of reasoning of its own.

The supervisory and office division usually includes the plant superintendent and his assistant, the clerk who frequently doubles in brass as stockroom man, and the results engineer. Again, the results engineer and the assistant superintendent are frequently the same individual and may also be the plant chemist and instrument maintainer.

The maintenance division usually includes one mechanical and one electrical repairman and a general helper. The janitor frequently reports to this group. In coal burning plants there is a small group, generally two, who handle coal and ashes. They also do most routine maintenance of the coal and ash handling equipment. Where fuel requirements are large, more men are needed. This group is sometimes known as "material handlers." These men are not needed where only oil and gas are burned.

As the division names imply, there is one group of men who are responsible for the overall performance of the plant in all its phases, a group who are responsible for operating the equipment, a group who are responsible for maintaining the plant, and a group who are responsible for handling fuel.

This division of duties has developed in the industry as a matter of necessity because of the size and complexity of the modern steam power plant. In a multi-unit plant, when one unit is out for maintenance, the other unit is normally still in service and the operating labor requirements are only slightly reduced.

Visitors to power plants occasionally come up with some remark such as "why so many men sitting around doing nothing?" It is perfectly true that as far as physical exertion is concerned, the average operator does little. However, his button pushing or knob twisting at the correct time, in the correct direction, and by the right amount, decides in large measure whether the plant burns only the amount of fuel needed or whether it burns much more than needed. The operator's buttons also have a great deal to do with maintenance cost. One would naturally think "why not make it all automatic and save the operator's wages?" There are two reasons for not eliminating operators. One is that in most localities the authorities will not permit unattended operation of high pressure steam equipment, the other is that no fully automatic steam plant of any considerable size has ever been built, although work has been done along these lines. Most plants today use only half as many men as were required by plants of the same size built a few years ago. Progress is being made but the operatorless steam plant still seems to be far off.

As there are fewer auxiliaries and the prime mover is practically self-contained it takes fewer men to run a greater number of units in an internal combustion plant than in a steam plant. Some internal combustion plants are semi-automatic where it is possible for the units to be shut down by protective relays but they must be started manually. This system is used on nighttime shifts for real small plants but one must contend with plant outages in the event of trouble. There is however, a point of no return as far as labor in internal combustion plants is concerned because large internal combustion engines are small compared to steam turbines. The size of internal combustion plants is economically limited to a combination of fuel burned and the number of men necessary to operate the plant. The largest internal combustion engine used by REA borrowers is 3100 kw and the largest REA plant is 13,000 kw. It is generally thought that 25,000 to 30,000 kw is the largest practical internal combustion electric utility plant but new thoughts on design of plant, methods of operation and maintenance and automatic operation could increase the size of gas burning combustion plants. Industry is using large size multi-unit internal combustion plants to produce low cost power. The Aluminum Company of America plant has 120 units aggregating 120,000 kw in operation at Port Lavaca, Texas.

Fuel

Internal combustion and steam plants are commonly known as thermal plants because their primary energy source is derived from the burning of fuel. The fuel can be anything which will burn but in REA-financed power plants the fuel is limited to oil, gas and coal. Actually all three types of fuel can be burned in steam or internal combustion plants but coal in internal combustion engines has not been developed to be practical for power plants. The energy contained in the fuel is measured by the heat content of the fuel in British Thermal Units or BTU's. A cubic foot of natural gas has from 850 to 1100 BTU; a gallon of oil, 132,000 to 150,000 BTU; and a pound of coal, 6000 to 14,000 BTU. Prices delivered to the plant range from 10 to 40 cents per 1000 cubic feet of gas, oil from 5 to 12 cents per gallon and coal from $3.00 to $14.00 per ton. Prices of the different fuels on a cents per million BTU is:

Gas - 13 to 40 cents per million with the average 20 to 25 cents per million.

Coal - 15 to 70 cents per million with the average 25 to 40 cents per million.

Oil - 40 to 125 cents per million with the average 70 to 85 cents per million.

In regard to the fuel itself two things affect its price; (a) location relative to source and markets, (b) quality. All gas is approximately the same in quality and markets and location to source are the greatest factors affecting costs. Oil costs vary primarily with the grade with markets and location to source having some effect. Coal has the greatest variables as to both location to source and quality with transportion costs an important factor. An illustration of the effect of transportation costs: North Dakota 42 pays 18¢ per million BTU, 10 miles from the mine, and North Dakota 20 pays 31¢ per million BTU, 200 miles from the same mine. For 200 miles the transportation cost is almost equal to the actual fuel cost.

In many cases it has been profitable to invest considerable sums in barge docking and unloading facilities to gain the price advantage of water transportation. Savings in the amount of 50¢ per ton are not unusual under this system. Where enough tons are to be burned so that the saving will be more than enough to amortize the investment, these facilities are usually provided. Unfortunately, many rivers do not have barge service, and some plants are not located on rivers or lakes.

Another item of considerable importance in cost of coal is purchasing power and available storage space. These factors frequently enable a large user of coal to buy so-called "distress coal" at appreciable savings in costs.

As to the quality of both oil and coal the lower the grade the more difficult it is to burn. This means additional investments, operation and maintenance costs for processing before and after burning lower grade fuels. For example, a diesel engine can burn residual fuel which costs 3 to 4 cents per gallon less than regular fuel but it must be heated and filtered before burning and some types of residual fuel will increase the maintenance costs on the engines so greatly that the savings are wiped out. Steam plants can use lignite, peat or low grade coal but the transportation costs may wipe out the savings if the plant is distant from the mine. Fuel is highly competitive and power plants burning different types have the advantage of being able to play one off against the other. Combinations of fuels and compromises of grade of fuels are used but a generalization can be made that the cost of power

will increase with the type of fuel burned with gas the cheapest, then coal, then oil.

In many parts of the country, the gas picture is changing due to the overall change in the fuel picture. Many gas burning plants have had price increases of 30 to 50 percent in the last year or two. It seems reasonable to assume that as storage is developed to enable gas transmission pipe lines to operate year around at 100 percent load factor, the availability of dump gas will decrease and the price will increase. Since gas is a nearly ideal fuel for most purposes, it is not likely to sell permanently for a lower price than less desirable fuels. These things must receive serious thought during the planning stage. Since practically all large volume gas contracts for powerhouses are on an interruptible basis, provisions for a secondary fuel are normally made. Whether this secondary fuel is oil or coal depends on the economic balance between investment costs, coal versus oil prices, and anticipated amount of energy to be produced annually from the secondary fuel.

Operating Supplies and Expenses

Generally speaking, this is a catchall for everything except labor, fuel, and maintenance material. There are however, two major exceptions - lubricating oil for internal combustion plants and water for steam plants. As either of these items could be substantial amounts, they are separated from the remainder of the report.

Maintenance Material

This item is self-explanatory and includes all material used in maintaining the power plant.

Production Expense - Efficiency

In the planning and operating stages of a thermal plant there is an item which must be given consideration that is not shown in dollars or mills per kwh and that is the efficiency of the plant. This item is most subject to day by day control and affords a tremendous opportunity to effect savings or, if neglected, might result in the plant operating in the red. It has been pointed out that fuel is the greatest expense item and that fuel is paid for in cents per million BTU. Naturally, if it takes fewer BTU's to make a kwh with all other things being equal, the production cost of power will be less for any given fuel cost. An internal combustion plant takes from 9600 to 13,000 BTU to make one kwh and a steam plant from 12,000 to 23,000 BTU's to make one kwh. These figures apply to the size of units used by REA-financed plants but for a rule of thumb - size for size - an internal combustion unit is more efficient than a steam unit and a 1000 kw internal combustion unit is as efficient as a 50,000 kw steam unit. A good operating engineer is forever chasing BTU's trying to save a few here and a few there. One of the best fields for saving BTU's is the loading on the unit. Typical efficiency curves for various internal combustion units are shown in Fig. 2.

Production Expense - KWH

When planning the cost of power, someone must stick their neck out and predict the expected loads. The loads not only affect the total cost in dollars but inversely affect the rate in mills per kwh. As pointed out in the efficiency curves, as the load increases the rate of cost per kwh decreases. Similarly, a spreading of overhead costs over a greater number of kwh's reduces the rate in mills per kwh. It is this reasoning which allows any surplus power to be sold at lower rates and the rates to be lowered with increased usage.

If the expected loads do not develop, not only is the income reduced but the total production costs are proportionately higher. This two-edged sword cuts down

the net margin very quickly. The planning engineer figures the plant as being an average plant - not too good but not too bad - and there is not much the operating engineer can do if the load is not available. As the net margin is only a small percentage in the first place, as the margin actually comes from the top part of the load curve, and as there is little that can be done with the plant under the circumstances, meeting the anticipated loads is vital to the well being of the cooperative. Not meeting the anticipated load is an accumulative error which increases costs all along the line from the basic energy source of fuel to the meter of the ultimate consumer. If the load is not there you are in trouble - real trouble.

Fig. 3 is a typical monthly operating report for a steam electric generating plant.

Fig. 4 shows the operating data for REA-financed internal combustion plants.

Fig. 5 shows the operating data for REA-financed steam plants.

System Operation

For a system with more than one plant the operating engineer must consider in addition to the production expenses for each unit within a plant, the effect of each plant and other power sources on the overall system costs, adequacy and reliability. Fig. 6 shows the system load curve for the day of maximum demand during a month for an REA cooperative. There are two internal combustion plants, both burning oil and connected together by a transmission line. There is no other source of power or interconnections. The plant statistics are as follows:

	Plant A	Plant B
Capacity kw	3939	3082
Production expense M/Nkwh	8.62	11.31
Fuel and lube M/Nkwh	6.53	8.03

With a difference in fuel costs of 1.50 mills per kwh the lowest overall costs would result from supplying as many kwh's as possible from Plant A. With 3939 kw and a 10 percent overload it should be possible to meet loads of 4333 kw from Plant A. This would mean we could just squeeze by the noon-time peak and run Plant B for about one and one-half hours during the evening peak. However, as we do not know how high the peak is going, as a sudden load may come on at anytime and as a failure may happen at anytime, the operator must allow for some immediate reserve which is called "spinning reserve." From our efficiency curves we can make a chart similar to Fig. 7. This is a ready reference of which units and plant to run for a given load. However, this cooperative cannot operate this way. Plant A is operated at a normal maximum load of 3200 kw because running the engines at anything above this load increases maintenance costs considerably. This is a serious handicap and detailed studies should be made of the exact increase in costs and the causes of increased maintenance. However, there are other problems. With all the load being supplied by Plant A the voltage drops due to inadequate transmission lines, which limits the load that can be carried by Plant A along to 2100 kw. If these plants could carry their nameplate rating and the transmission line could carry the load, it is conservately estimated that $7,000 to $10,000 a year could be saved in fuel alone. This amounts to from 5 to 7 percent of the total fuel costs for this borrower. It also represents the interest and amortization charges on a capital expenditure of $180,000 to $250,000. Running a higher cost plant at the end of a transmission line to maintain voltage is an expensive way to get voltage regulation. It is true that some plants are designed and built as end of the line plants but these are special cases.

Fitting hydro plants and purchased power into the load curves takes individual studies. Some purchased power contracts have rachet charges on demand and once a demand is reached the demand charges apply whether it is used or not. The output of the hydro plants depends on the availability of water which varies from season to season and sometimes from day to day. Another equally important factor with hydro plants is the amount of storage capacity. The problem is whether you want kw or kwh and how can you fit what you have when you want it.

Maintenance of Generating Plants

The number of items and check points to be maintained for even a small generating plant runs into the thousands. The Federal Power Commission lists over 100 units of property for "Boiler Plant Equipment" alone for a steam plant. Most of these items are multiplied by the number of generating units in the plant. The maintenance man must consider each unit of property in terms of its component parts and the component parts must be considered in terms of daily, weekly, monthly and yearly.

There are two basic maintenance methods and both are used in varying degrees in maintaining the plant. One is that after a certain amount of hours the equipment be taken out of service if necessary, inspected and repaired. The second method is not to take the equipment out of service until there is some evidence it is not performing properly. The second theory is not one of locking the door after the horse is gone but one of keeping detailed and continuous records of performance and watching gradual changes. Figs. 8 and 9 show illustration of the two methods. The maintenance personnel of a generating plant are expected to repair and maintain any item within the plant. Sometimes this repair is done under the supervision of a factory representative. There are, of course, some things which cannot be repaired in the field and they must be returned to the factory. There are other things which cannot be repaired at the plant simply because of inadequate repair facilities and tools. All plants have some repair facilities and some plants have elaborate facilities. What is provided is dependent upon the thinking of management and location and access to other repair facilities. Again this becomes a problem of the individual plant or system.

CONCLUSIONS

In the overall operation and maintenance of a generating plant there are many thousands of things to be considered. Although there are definite patterns for some, each one is dependent upon and affects the other. Behind it all is how does each piece fit into providing adequate, reliable, low-cost power.

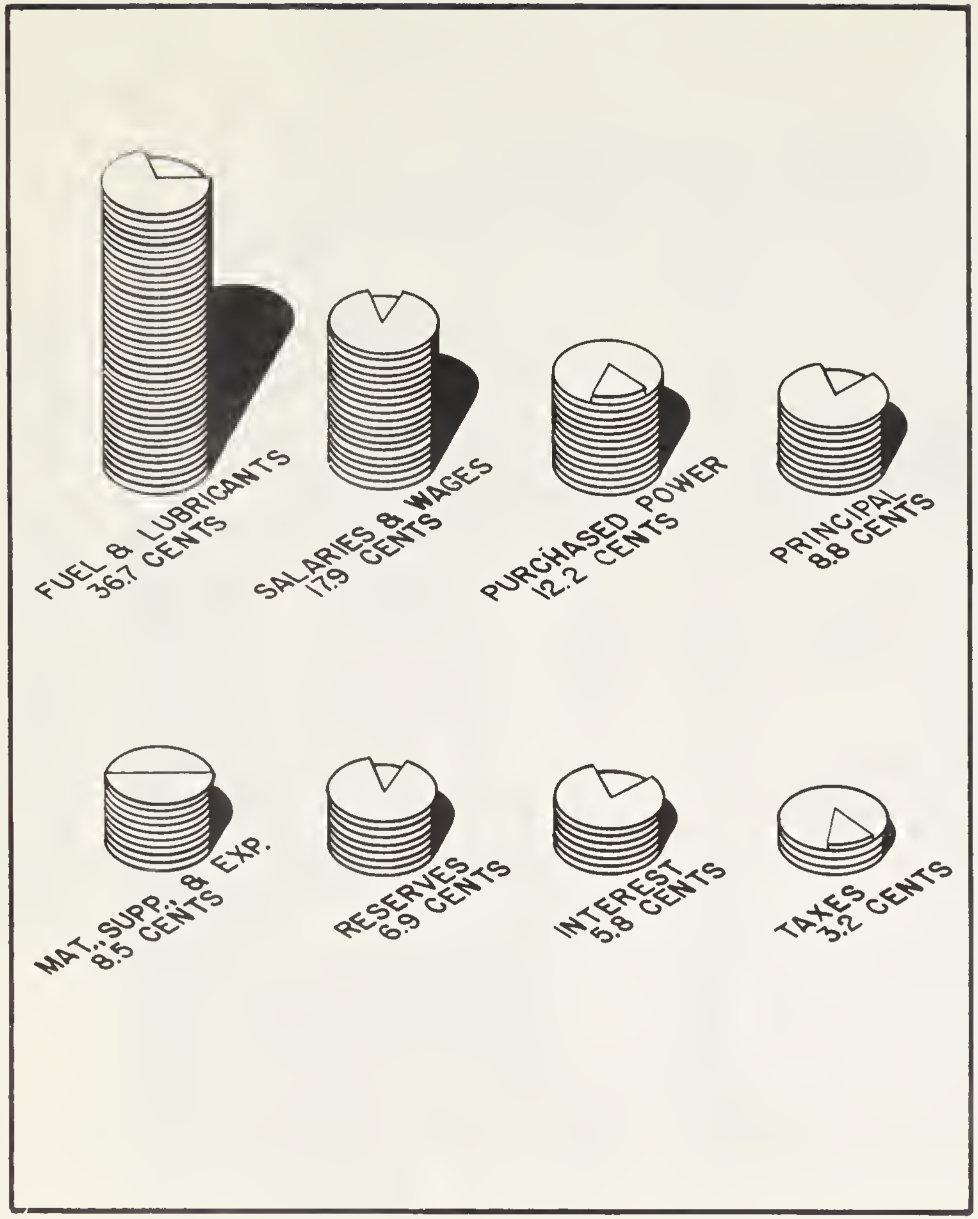

Fig. 1. Disposition of 1952 revenue dollar

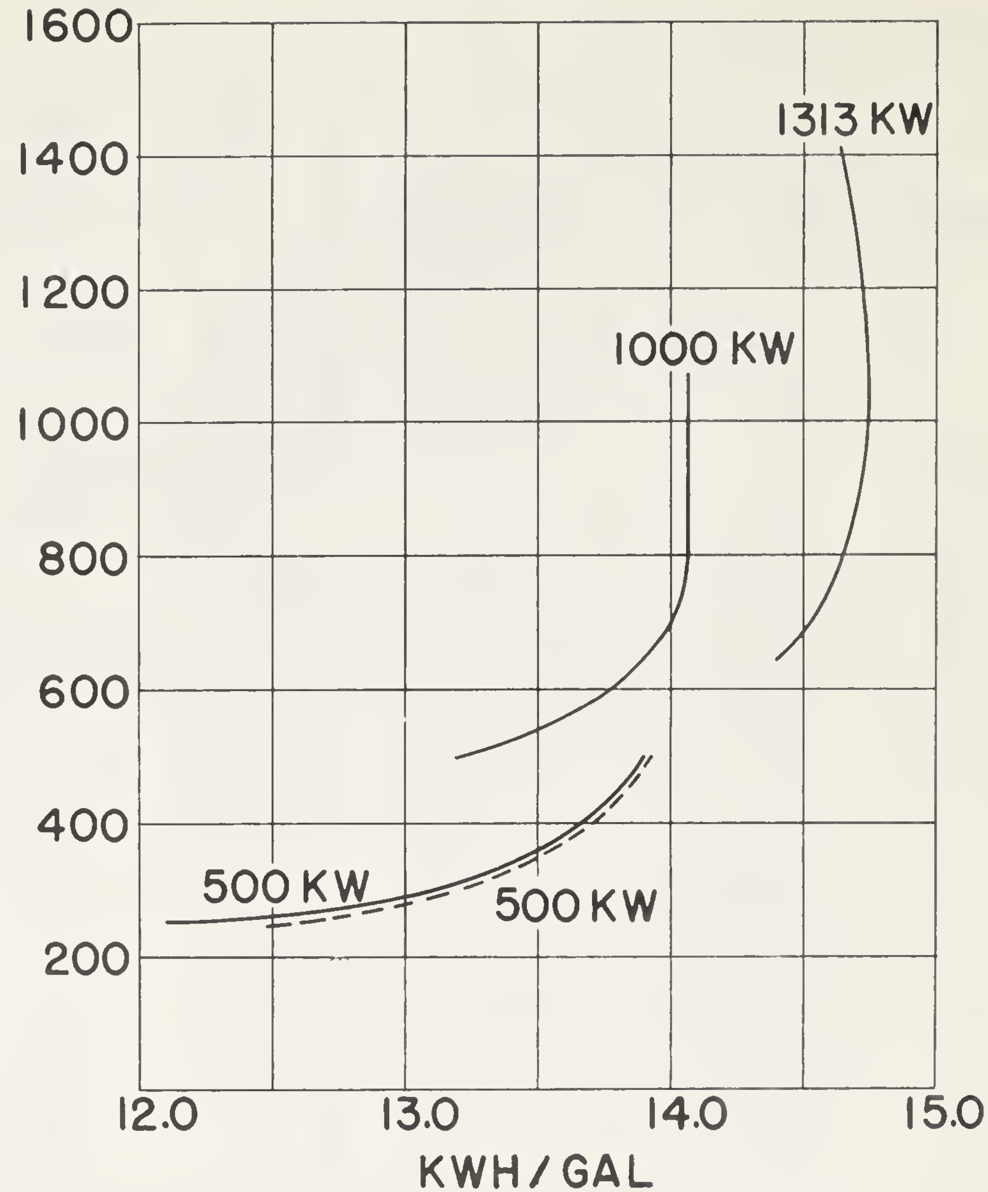

Fig. 2. Typical efficiency curves - internal combustion

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RURAL ELECTRIFICATION ADMINISTRATION

BUDGET BUREAU NO. 40-R568

MONTHLY PLANT OPERATING REPORT
STEAM-ELECTRIC GENERATING PLANT

BORROWER DESIGNATION Washington, D. C. 1 PLANT Mount Vernon MONTH ENDING April 30, 1949

BOILERS

NO.	SIZE 1000 LBS. STEAM/HR.	HOURS OPERATED THIS YEAR	HOURS OPERATED THIS MONTH	HOURS OPERATED SINCE MAJOR OVERHAUL	TIMES STARTED	FUEL CONSUMPTION COAL 1000 LBS.	FUEL CONSUMPTION OIL 1000 GAL.	FUEL CONSUMPTION GAS 1000 M.C.F.	STEAM GENERATED TOTAL 1000 LBS.	STEAM GENERATED LBS. PER UNIT FUEL	BOILER EFF.-%
1	190	2491	650	12,918	13	10,044	1,085		92,155	9.17	84.9
2	190	2587	624	11,892	17	9,476	1,424		86,220	9.10	84.2
3	120	2604	660	10,945	18	7,429	1,511		67,975	9.15	84.7
4											
5											
TOTAL	500	x x	x x	x x x		26,949	4,020		246,350	9.14	xxx

TURBINES

NO.	SIZE KW	HOURS OPERATED THIS YEAR	HOURS OPERATED THIS MONTH	HOURS OPERATED SINCE MAJOR OVERHAUL	GROSS GENERATION 1000 KWH THIS YEAR	GROSS GENERATION 1000 KWH THIS MONTH	STEAM USED TOTAL 1000 LBS.	STEAM USED LBS. PER KWH	FUEL PER GROSS KWH
1	15000	2528	640	13,210	36,779	9,452	92,155	9.75	1.063
2	15000	2597	616	10,980	37,893	9,014	86,220	9.57	1.051
3	11500	2611	654	9,750	28,649	7,075	67,975	9.61	1.050
4									
5									
TOTAL	41500	x x	x x	x x x	103,321	25,541	246,350	9.65	1.055

FACTORS - %

Load	74.5
Plant	85.5
R.P.C.	96.8

MAXIMUM DEMAND KW

15 Min.	47600
Ind.	48000

OVERALL PLANT THERMAL EFF. Net 26.9 %

	This Year	This Month
Station Service, 1000 KWH	5,429	1,266
Net. Generation, 1000 KWH	97,892	24,275
Station Service, % of Gross	5.3	5.0

Avg. Boiler Pressure 900 Psia. Steam Temp. 800 °F.
Avg. Boiler Feed Water Temp. 360 °F.

Average Btu per Lb. Coal	11,450
Average Btu per C.F. Gas	
Average Btu per Gal. Fuel Oil	
Btu per Gross KWH	12,080
Btu per Net KWH	12,710

COST COMPUTATION OF NET ENERGY GENERATED

ITEM NO.	EXPENSE ITEMS		REA ACCOUNT NUMBER	THIS YEAR TOTAL DOLLARS	THIS YEAR MILLS PER NET KWH	THIS MONTH TOTAL DOLLARS	THIS MONTH MILLS PER NET KWH
1	Operation, Supervision and Engineering		701	2,960.00	x x x	760.00	x x x
2	Station Labor		702	28,725.60	.29	7,466.75	.31
3	Fuel, Coal		703.1	427,235.60	4.36	105,125.94	4.33
4	Fuel, Oil		703.2				
5	Fuel, Gas		703.3				
6	Water		704	2,060.00	x x x	510.00	x x x
6a	Other Operating Supplies and Expenses		705	1,252.00	x x x	312.00	x x x
7	x x x x x			x x x x	x x x	x x x x	x x x
8	Maintenance, Supervision and Engineering		706	1,092.00	x x x	332.00	x x x
9	Maint., Structures and Imp.	Labor	707	890.00	x x x	266.45	x x x
	" " " "	Material	"	210.00	x x x	56.90	x x x
9a	Maintenance, Boilers	Labor	708	7,616.00	x x x	1,448.60	x x x
	" "	Material	"	3,390.00	x x x	425.25	x x x
9b	Maint., Generating & Elec. Equip.	Labor	709	4,290.00	x x x	855.85	x x x
	" " " " "	Material	"	2,426.00	x x x	151.64	x x x
10	**Sub-Total**, Items 1 to 9b			482,147.20	4.93	117,711.38	4.85
11	Rents		710	—	x x x	—	x x x
12	Other Miscellaneous Expenses		711 to 714	266.83	x x x	125.67	x x x
13	**TOTAL PRODUCTION EXP.** Items 10 to 12			482,414.03	4.93	117,837.05	4.85
	OVERHEAD COSTS (PRORATED)			x x x x	x x x	x x x x	x x x
14	Depreciation		503.1	69,309.48	x x x	17,327.37	x x x
15	Taxes		507	20,872.28	x x x	5,218.07	x x x
16	Interest		530	58,270.32	x x x	14,567.58	x x x
17	Insurance		798, 799	7,866.39	x x x	2,149.57	x x x
18	Other Administrative and General			13,697.00	x x x	3,515.72	x x x
19	**TOTAL OVERHEAD COSTS**, Items 14 to 18			170,015.47	1.74	42,778.31	1.76
20	**TOTAL PRODUCTION COST**, Item 13 + 19			652,429.50	6.66	160,615.36	6.62

OPERATING INVENTORY	COAL TONS	COAL $/TON	COAL TOTAL $	OIL GALLONS	OIL $/GAL.	OIL TOTAL $	MAT. & SUP. DOLLARS
On Hand, First of Month	67,692.75	7.7312	523342.56	6889	.1189	819.10	8563.75
Purchased During Month	3,741.70	6.965	26062.04	3000	.1189	356.70	850.00
Used During Month	13,474.50	7.691	103640.07	4020	.1189	477.96	1097.43
On Hand, End of Month	57,959.95	7.691	445764.53	5869	.1189	697.84	8316.32

LABOR

No. Full Time Employees 34
No. Part Time Employees 3

	REGULAR TIME	OVERTIME	TOTAL
Man-Hours - Operation	4520	296	4816
Man-Hours - Maintenance	1210	170	1380
Man-Hours - TOTAL	5730	466	6196

PLANT OUTAGES

NO.	DURATION	REMARKS
7	7 min.	Lightning storm

(Use reverse side if necessary)

(See Other Side)

Fig. 3. Monthly plant operating report - steam electric generating plant

U. S. DEPT. OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION

OPERATING DATA OF CERTAIN REA-FINANCED INTERNAL COMBUSTION GENERATING PLANTS - JANUARY 1, 1954 TO JUNE 30, 1954

PROJECT	PLANT LOCATION	SIZE KW	GROSS GEN. MWH	% STATION SERVICE	PLANT FACTOR %	R P C FACTOR %	FUEL — COST CENTS/10^6 BTU OIL	FUEL — COST CENTS/10^6 BTU GAS	BTU PER KWH	HP/HRS PER GAL. LUBE	LABOR OPER. $	COST MAINT. $	MAINT MATL. $/KW	PRODUCTION EXPENSE MILLS/NET KWH LABOR	FUEL	OTHER	TOTAL
ALA-3	KODIAK	2010	2.021	4.6	23.2	62	104	-	10315	3296	14700	2515	.42	8.82	11.28	1.68	21.78
ALA-5	HOMER	550	.376	3.3	15.8	47	126	-	13292	1786	5303	247	-	15.24	17.28	10.85	43.37
ARIZ-17	THATCHER	3500	3.027	4.7	20.0	84	103	25.0	9658	3894	7198	1562	.85	2.38	3.27	2.31	7.96
FLA-14	KEYSTONE	3946	7.094	4.7	50.0	67	42	-	10700	2009	13275	3561	.29	2.37	4.68	1.35	8.40
FLA-14	WORTHINGTON	4600	8.187	3.9	41.0	68	42	-	10477	2217	8906	2315	1.13	1.37	4.56	1.66	7.59
FLA-24	TAVENIER	2900	6.922	2.5	55.0	76	79	-	10117	1186	10510	678	1.22	1.62	8.18	1.86	11.66
ILL.18	WINCHESTER	3200	4.931	3.5	35.5	75	59	-	10288	3658	12997	1774	1.89	2.99	6.75	2.08	11.82
ILL.18	PITTSFIELD	3480	8.429	3.5	56.0	94	80	29.5	10783	5203	11117	869	.46	1.47	3.69	.78	5.94
KANS-34	GR.BEND	4320	13.685	2.3	73.0	81	79	16.0	9925	7275	14005	4810	.36	1.37	2.32	.62	4.31
KANS-38	SEDAN	2646	3.349	4.5	29.2	61	67	16.0	11618	17120	7867	1499	.30	2.93	4.36	.66	7.95
KANS-44	ULYSSES	3324	5.183	6.0	38.3	62	79	19.3	11916	6262	8229	5186	1.56	2.59	2.84	1.40	6.83
KANS-51	SCOTT CITY	9380	12.966	3.1	31.8	67	74	23.2	10876	2864	11975	2887	.25	1.18	3.67	.69	5.54
MICH-37	UBLY	3082	4.154	4.1	31.0	88	68	—	10724	3250	10420	796	.62	2.82	7.59	.88	11.29
MICH-37	CAIRO	3939	8.154	2.7	48.0	65	67	—	9555	9700	10327	3737	.57	1.77	6.55	.57	8.89
MICH-42	SCOT'VILLE	3220	6.497	4.6	46.6	79	69	38.3	9777	3870	11733	747	.43	2.39	6.41	.80	9.60
MICH-46	BIRNIPS	1805	2.503	6.2	32.0	68	70	20.3	10362	3100	8774	1363	3.25	4.31	5.31	3.37	12.99
MICH-46	PORTLAND	4086	3.301	2.8	18.6	83	68	—	9926	2400	10560	1225	.26	3.67	6.93	.96	11.56
MICH-46	HERSEY	10065	22.158	2.7	51.0	75	75	33.4	9247	2960	13263	4390	.19	.82	3.60	.48	4.90
MINN-37	JACKSON	4920	8.953	4.3	42.0	68	86	35.9	10154	10400	11119	1890	.54	1.52	4.54	.62	6.68
MINN-98	BENSON	6525	9.462	4.8	33.4	60	56	—	10074	12300	14080	1492	.09	1.73	5.98	.56	8.27
MINN-99	WARROAD	3885	5.701	5.5	34.8	72	87	—	10258	5710	10499	765	.28	2.09	9.47	1.06	12.62
MO-60	P.BLUFF	9404	25.736	3.4	63.0	96	72	30.0	9631	9719	18939	4137	.20	.93	3.38	.32	4.63
N.MEX-11	TAOS	1801	3.848	9.0	49.0	84	72	—	11181	4370	9248	3069	3.10	3.52	8.84	2.20	14.55
N.MEX-22	GRANTS	3250	5.371	2.9	38.0	67	85	—	13293	4400	9852	5438	1.15	2.93	11.60	1.74	16.27
N.MEX-23	LOVINGTON	12030	13.671	3.6	25.6	74	65	19.0	11345	2780	21316	93	.02	1.63	2.76	.68	5.07
N.MEX.28	ESPANOLA	3976	7.035	3.9	41.0	66	77	—	11973	2860	12358	3720	.71	2.23	9.60	1.57	13.40
N.CAR.63	OCRACOKE	220	.209	4.3	21.9	69	107	—	16211	4361	2032	262	4.40	9.83	18.12	1.63	29.58
N.CAR.64	BUXTON	800	.874	6.9	24.7	77	95	—	11710	3280	4944	64	.58	6.20	11.90	1.20	19.30
WIS. 59	WASH.ISLD.	570	.376	7.6	15.7	54	97	—	11655	4648	451	628	.68	3.10	12.10	2.50	17.70
WIS. 64	TWIN LAKES	10400	10.008	2.6	22.2	72	90	31.4	10498	5563	20394	14470	.64	3.58	5.87	1.34	10.79
WYO. 9	LYMAN	1480	1.733	3.9	27.1	64	87	32.7	10888	17756	7827	1478	.64	5.65	4.32	.85	10.82

Fig. 4. Operating data - internal combustion plants

U. S. DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION

SUMMARY OF OPERATING DATA FOR SELECTED COOPERATIVE-OWNED STEAM PLANTS
FOR THE FIRST HALF OF 1954
BORROWERS AND PLANT LOCATION

	ALASKA 6 * AND ** FAIRBANKS	ALASKA 8 * ANCHORAGE	COLORADO 36 ** MCGREGOR	IOWA 81 CRESTON	IOWA 83 CEDAR RAPIDS	IOWA 84 HUMBOLDT	MICHIGAN 47 ADVANCE	MINNESOTA 70 ELK RIVER	MISSOURI 70 SOUTH RIVER	MISSOURI 71 CHAMOIS	N. DAKOTA 20 GRAND FORKS	NORTH DAKOTA 40 BEULAH	NORTH DAKOTA 42 VELVA	OKLAHOMA 32 ANADARKO	S. DAKOTA 44 OSAGE (WYO.)	TEXAS 121 BELTON	WISCONSIN 64 ALMA	WISCONSIN 64 CASSVILLE
NUMBER AND SIZE OF UNITS NAMEPLATE RATING	1-500 3-3000	1-500 3-3000	1-1250 1-1500 1-2500	2-7500	2-20000	2-7500 1-11500 1-15000	2-7500	2-11500	2-7500	1-15000	2-5000 1-11500	1-7500	2-15000	2-15000	1-10000	2-11500	3-15000	1-15000 1-30000
OPERATED BY	OTHER	CO-OP	CO-OP	CO-OP	OTHER	CO-OP	CO-OP	CO-OP	CO-OP	CO-OP	CO-OP	OTHER	CO-OP	CO-OP	OTHER	CO-OP	CO-OP	CO-OP
FUEL	C-L	C	C	G-C	G-C	G-C	C	C	C-G	C	L	L	L	G-O	L	G-O	C	C
METHOD OF FIRING COAL	S	S	S	S	S	3S 1P	P	S	S	P	S	S	P	–	S	–	P	P
FUEL COST ¢/10^6 BTU	65	68	15	26	24	28	33	36	26	27	31	16	18	14	15	15	29	29
BOILER EFFICIENCY %	78	81	NA	83	83	81	78	83	84	86	77	78	75	85	79	81	85	82
STATION HEAT RATE BTU/NKWH	24108	12600	24570	14900	12500	13940	17900	14000	14100	12600	15100	17900	14000	13200	14800	13300	12900	12300
STATION SERVICE, % OF GROSS	9.5	5.2	4.0	7.4	4.9	6.0	8.8	5.5	6.3	7.9	6.2	9.8	8.1	9.4	7.7	6.1	6.5	7.2
PLANT FACTOR %	39	66	31	39	87	55	29	72	44	88	70	53	67	49	82	55	71	51
R.P.C. FACTOR %	NA	90	65	78	95	83	59	77	85	105	76	54	82	74	NA	78	96	73
FUEL COST M/NKWH	15.58	10.73	3.58	3.89	3.00	3.84	5.84	4.97	3.68	3.46	4.69	2.94	2.48	1.87	2.21	2.05	3.78	3.61
OPER. LABOR, INCL. SUPV. & ENG. M/NKWH	3.43	2.12	2.93	1.52	.32	.59	2.23	.55	1.33	.51	.65	1.48	.60	.53	.56	.78	.38	.43
MAINTENANCE COST M/NKWH	3.19	.77	.84	.39	.22	.22	.42	.34	.41	.23	.32	.19	.22	.27	.40	.23	.23	.19
MISCELLANEOUS COST, M/NKWH	.60	.25	.12	.13	.06	.08	.23	.08	.31	.13	.09	.45	.21	.21	.10	.08	.02	.04
PRODUCTION EXPENSE, M/NKWH	22.80	13.87	7.47	5.93	3.60	4.73	8.72	5.94	5.73	4.33	5.75	5.06	3.51	2.88	3.27	3.14	4.41	4.27
BEST HEAT RATE THIS YEAR	21200	11884	23000	14484	12311	13410	15557	13813	13888	12179	14572	17444	13452	12457	14700	12580	12481	12110
LOWEST AUX. PWR. THIS YEAR	6.3	5.3	3.6	6.5	4.4	5.7	8.22	5.1	5.5	6.4	5.7	6.5	7.5	7.7	7.2	5.4	6.0	6.6
LOWEST PROD. EXP. THIS YEAR	15.84	12.95	7.03	5.48	3.33	4.46	7.50	5.75	5.31	4.18	5.39	4.57	3.17	2.64	3.10	2.60	4.30	4.06
DID THESE OCCUR IN SAME MONTH	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO	NO	YES	YES	NO

NA - NOT APPLICABLE
C - COAL
G - GAS
O - OIL
L - LIGNITE
S - STOKER FIRED
P - PULVERIZED

* HEATING SYSTEM STEAM FURNISHED TO OTHERS FROM THESE PLANTS.
** PLANTS OVER TWENTY YEARS OLD.
STANDBY AND PEAKING PLANTS NOT SHOWN ON THIS REPORT.
DAWSON PLANT OF NEW MEXICO 18 WAS SHUT DOWN PERMANENTLY IN MAY.
EIGHTEEN PLANTS WITH NAMEPLATE CAPACITY OF 400,750 KW ARE SHOWN.

Fig. 5. Operating data - steam plants

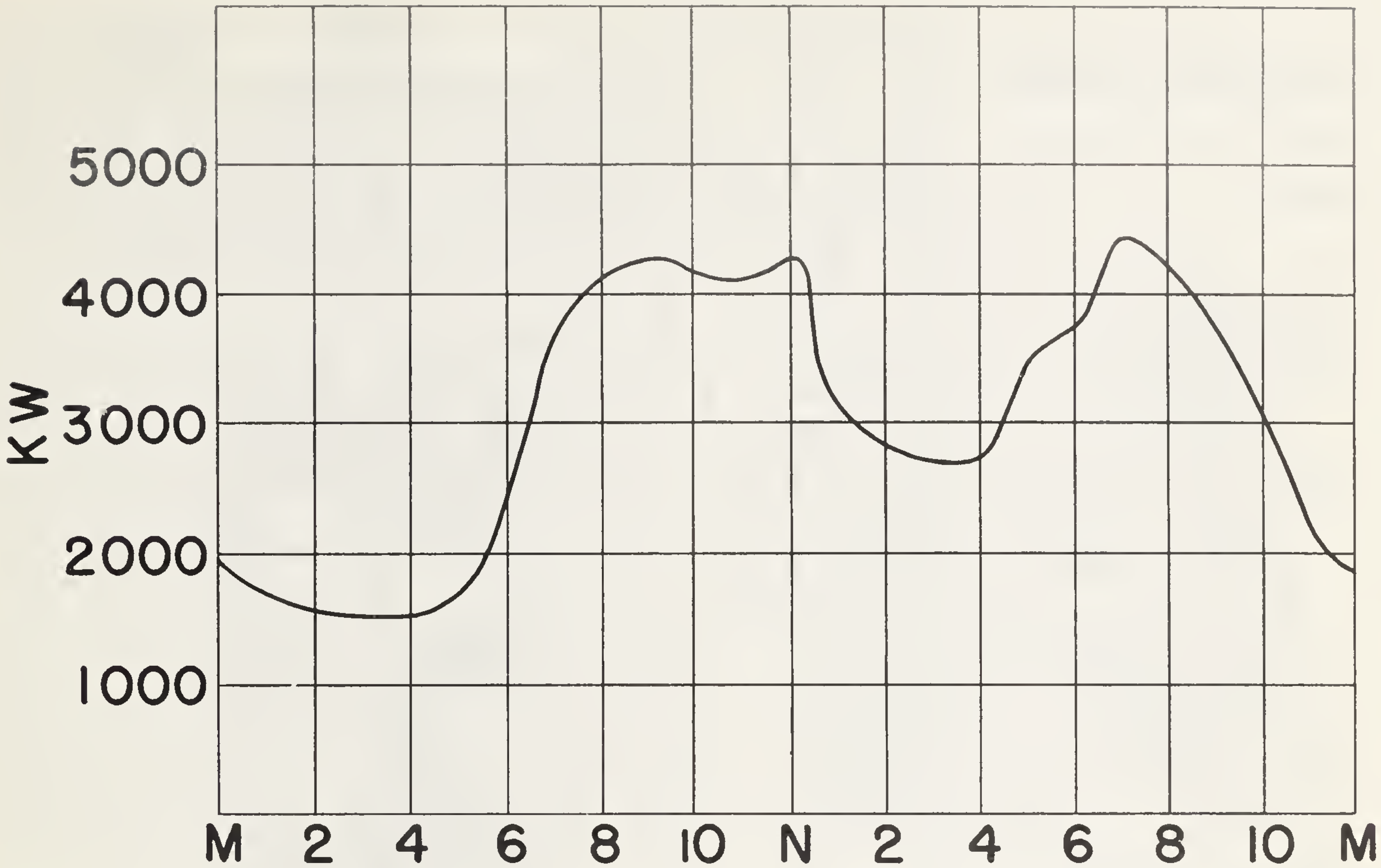


Fig. 6. System load curve

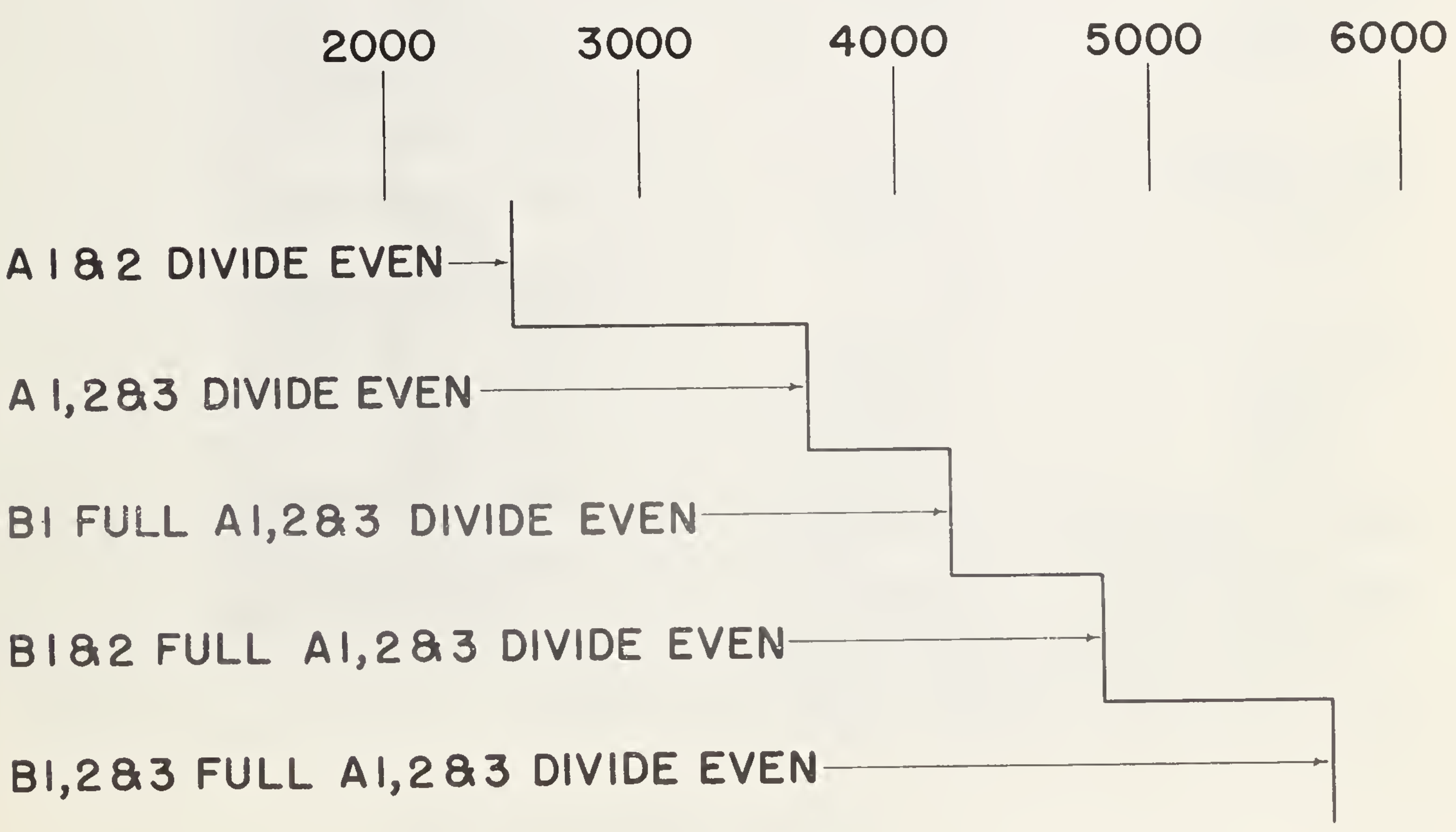


Fig. 7. Load chart

MAINTENANCE RECORD

UNIT No. ________

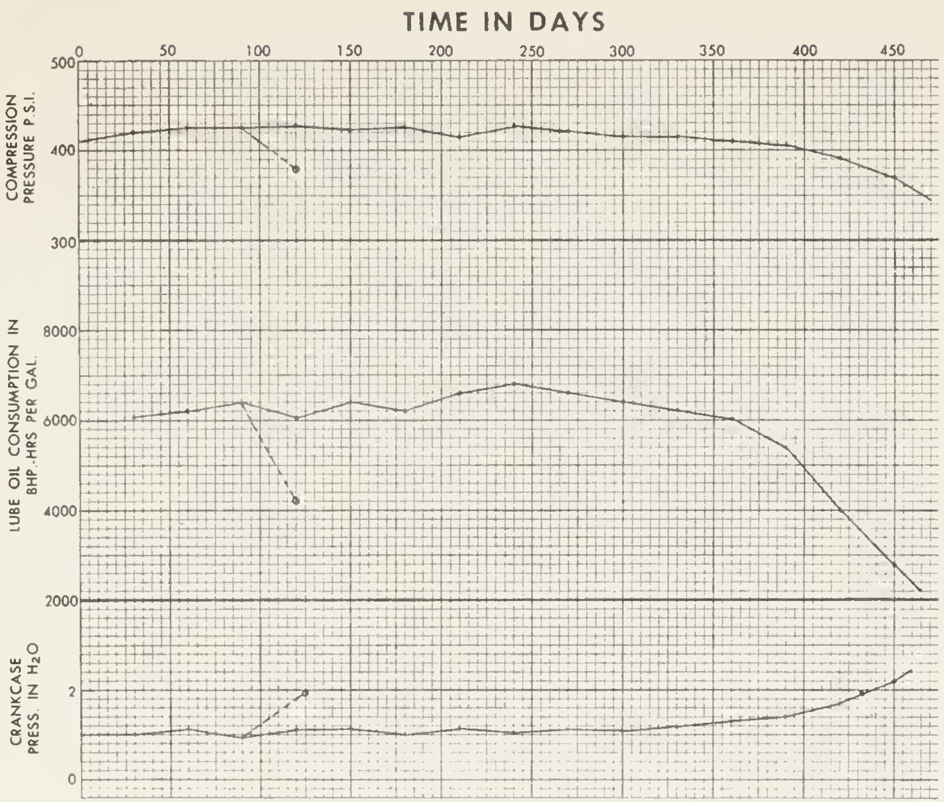
FROM ________

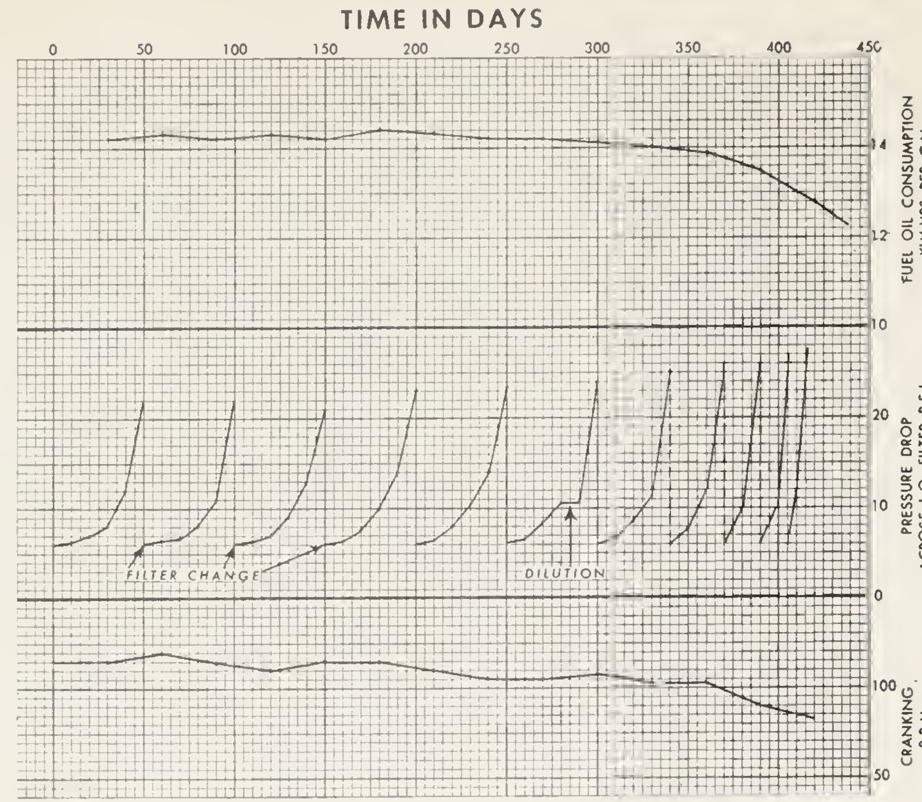
TO ________

Continued.........

	Recommended Hours Between Check	Check To Be Made Time Meter	Time of Check Time Meter	Work Accomplished: Cleaned	Calibrated	Lubricated	Renew Oil	Oil Level	Tightened	Overhaul	Stop Leaks	Operation	Reseated	Found: Satisfactory	Fair	See Remarks	OPERATOR
Inlet Valves	2000																
Tappets	300																
Rocker Arms	100																
Lubricating Oil																	
Filter	1000																
Strainer	1000																
Purifier Pump	100																
Motor	100																
Motor Switch	100																
Heater Switch	100																
Supply Tank	4000																
Levelometer	1000																
Lub. Oil Pump	1000																
Pressure Relief	1000																
Cooler	1000																
Pressure Gauges																	
Air	2000																
Fuel	2000																
Oil - Engine	2000																
Oil - Turbo Charge	2000																
Water	2000																
Pyrometer	2000																
Connections	1000																
Thermocouples	2000																
Tachrometer	3000																
Turbocharger	2000																
Therometers																	
Water	2000																
Oil	2000																
Water Pump																	
Motor	100																
Switch	100																
Packing	100																
Valves	100																
Voltage Regulator	2000																
Water Surge Tank	4000																
Sight Glass	100																

Fig. 8. Maintenance record





REMARKS ON DAILY READINGS

IF ANY CHANGES ARE NOTED IN FOLLOWING READINGS INCLUDE THE REMARKS BELOW. 1—EXHAUST TEMP., 2—PRE-TURBO TEMP., 3—WATER TEMP. TO & FROM ENGINE 4—LUBE OIL TEMP. TO & FROM COOLER, 5—LUBE OIL PRESS 6—AMT. VAPOR FROM CRANK CASE BREATHER, 7—COLOR OF EXHAUST, 8—SOUND OF ENGINE

ENGINE MAINTENANCE LOG FOR

......COMPANY......STATION UNIT NO....

WEEKLY READINGS

DATE	PRESSURE DROP ACROSS L.O. FILTER	AIR M'FLD PRESSURE	CRANK CASE PRESSURE	CHECK FOR LEAKS	DATE	PRESSURE DROP ACROSS L.O. FILTER	AIR M'FLD PRESSURE	CRANK CASE PRESSURE	CHECK FOR LEAKS
9	10	11	12	13	9'	10'	11'	12'	13'

MONTHLY READINGS

DATE	COMPRESSION PRESSURES								VALVE TAPPET CLEARANCE	L.O. BHP HRS. PER GAL.	HOURS OPERATED THIS MONTH	TOTAL HOURS	CRANKING R.P.M.	SEND L.O. SAMPLE	CHECK SAFETY DEVICES	DRAIN MOIST FROM F.O. & AIR TANKS	F.O. CONSUMPTION KWH/GAL.	REMARKS
	1	2	3	4	5	6	7	8										
14				15					16	17	18	19	20	21	22	23	24	

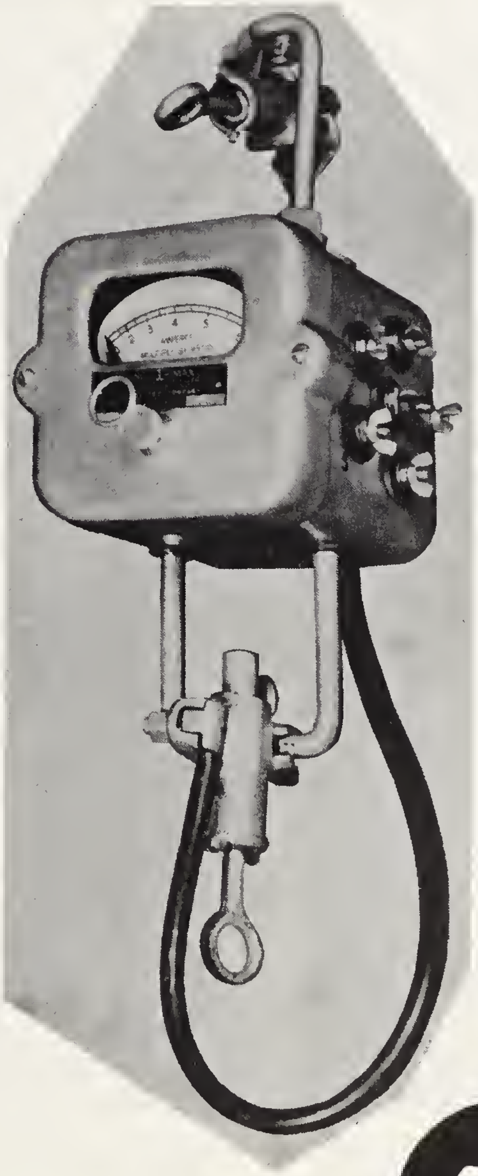
SEMI-ANNUAL READINGS

DATE	ROD BEARING CLEARANCES								CRANK WEB DEFLECTIONS								CRANK SHAFT THRUST	CRANK CASE INSPECTION	CHECK CHAIN TIGHTNESS	CHECK F.O. & VALVE TIMING	REMARKS
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8					
				25								26					27	28	29	30	

Fig. 9. Maintenance record

FOR DISCUSSION PURPOSES ONLY.
This paper in its present form does not necessarily represent official REA policy or procedures.

APPLYING THE "IND-I-MAX" AMMETER TO RURAL DISTRIBUTION CIRCUITS



By Roland W. Schlie
Harold W. Kelley
Electric Engineering Division

For Presentation at the Technical Conference for REA Field Engineers, Chicago, Ill., January 17-21, 1955

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

APPLYING THE "IND-I-MAX" AMMETER TO RURAL DISTRIBUTION CIRCUITS

Roland W. Schlie and Harold W. Kelley

Obtaining measurements of peak current on high-potential circuits is a relatively cumbersome and costly task. It is usually necessary to interrupt the load in order to install a required current transformer. The primary purpose of making a current measurement is to determine the peak current on the circuit. If the peak current could be determined without installing a current transformer and without interrupting the load, current measurements would be greatly simplified.

Efficient planning and operation of a distribution system requires a knowledge of circuit loading. For this reason REA has encouraged the development of an instrument which would provide a simple and inexpensive means of obtaining circuit loading data. An electrical equipment manufacturer* has cooperated with REA in developing such an instrument. It is called the "Ind-I-Max" Ammeter. An outline photograph of the meter appears on the cover.

A thermal element and current transformer are utilized in the instrument and are self-contained in the instrument housing. Full scale of the thermal element is six amperes. Two models are available, the R-30 with CT ratios of 5/5, 10/5, 15/5, 20/5, and 25/5, and the R-60 with CT ratios of 30/5, 35/5, 40/5, 45/5, and 50/5. The maximum pointer shows the peak amperes since the instrument was last reset. The indicating pointer shows, at all times, the amperes averaged over the immediately preceding 30 minutes. The maximum pointer can be reset by using a hot-stick.

The instrument may be connected directly into the high potential circuit without interrupting the load. Figures 1 through 7 illustrate the technique of installation. Removal of the instrument is accomplished by reversing the steps illustrated in the figures.

The "Ind-I-Max" Ammeter is useful for measuring peak amperes on single-phase feeders at substations, at any suitable location along the line, at taps along the line, and on the primary of transformers 25 kva and larger. A quick and simple installation can be made at any location where there is a jumper or tap.

A knowledge of peak amperes will facilitate balancing circuit loads and predicting circuit load growth.

* HD Electric Company, 760 Osterman Avenue, Chicago, Illinois

Fig. 1 CLIMBING POLE WITH METER IN HOT STICK

Fig. 2 CLAMPING METER ON PHASE WIRE (PREFERABLY OVER ARMOR)

Fig. 3 REMOVING METER LEAD FROM INSULATED LOOP

Fig. 4 CONNECTING METER LEAD TO PHASE TAP WIRE

Fig. 5 REMOVING PHASE TAP WIRE FROM LINE

Fig. 6 SECURING PHASE TAP WIRE TO INSULATED METER LOOP

Fig. 7 COMPLETED METER INSTALLATION

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APPLYING THE V-3 "MIN-MAX" VOLTMETER TO RURAL DISTRIBUTION SYSTEMS

By Roland W. Schlie
Harold W. Kelley
Electric Engineering Division

For Presentation at the Technical Conference for REA Field Engineers, Chicago, Ill., January 17-21, 1955

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

APPLYING THE V-3 "MIN-MAX" VOLTMETER TO RURAL DISTRIBUTION CIRCUITS

Roland W. Schlie and Harold W. Kelley

Obtaining measurements of minimum and maximum voltages on rural distribution circuits is a relatively cumbersome and costly task. It is usually necessary to install graphic voltmeters. The primary purpose of making voltage measurements is to determine the minimum and maximum voltages on the circuits. In some instances it may be required to know the time at which minimum and maximum voltages occur or to obtain a graphic record of the voltage during a specified period. However, for the majority of instances only the minimum and maximum voltages need to be known. If the minimum and maximum voltages could be determined without installing a graphic instrument, voltage measurements would be greatly simplified.

Efficient planning and operation of a distribution system requires a knowledge of the circuit voltages. For this reason REA has encouraged the development of an instrument which would provide a simple and inexpensive means of obtaining circuit voltages. An electrical manufacturer* has cooperated with REA in developing such an instrument. It is called the V-3 "Min-Max" Voltmeter. An outline photograph of the meter appears on the cover.

A thermal element is utilized in the instrument which is housed in a standard watthour meter enclosure. Two ranges are available, 95-135 volts and 190 to 270 volts. The black minimum and maximum pointers show the minimum and maximum voltage since the instrument was last reset. The red indicating pointer shows the average voltage for the immediately preceding ten minutes. The red indicating pointer is magnetically coupled to the meter movement when the meter has been energized for sufficient time to overcome thermal lag. During an outage the red indicating pointer is not coupled to the meter movement. Therefore outages do not cause false minimum indications.

The V-3 "Min-Max" voltmeter is useful for checking voltage at substations, at the ends of distribution lines, and at the consumers' watthour meter sockets. The meter may be used to check regulator output voltage, but readjustment of a voltage regulator should be based upon a continuous recording of regulated output voltage.

Figure 1 illustrates a permanent installation of a V-3 "Min-Max" Voltmeter at the end of a distribution line. Figure 2 illustrates the installation of a V-3 "Min-Max" Voltmeter, an ampere demand meter, and a watthour meter at the consumer's watthour meter socket.

A knowledge of voltage spreads throughout the entire distribution system will facilitate maintaining adequate voltage and predicting when circuit improvements will be required.

* Sangamo Electric Company, Springfield, Illinois

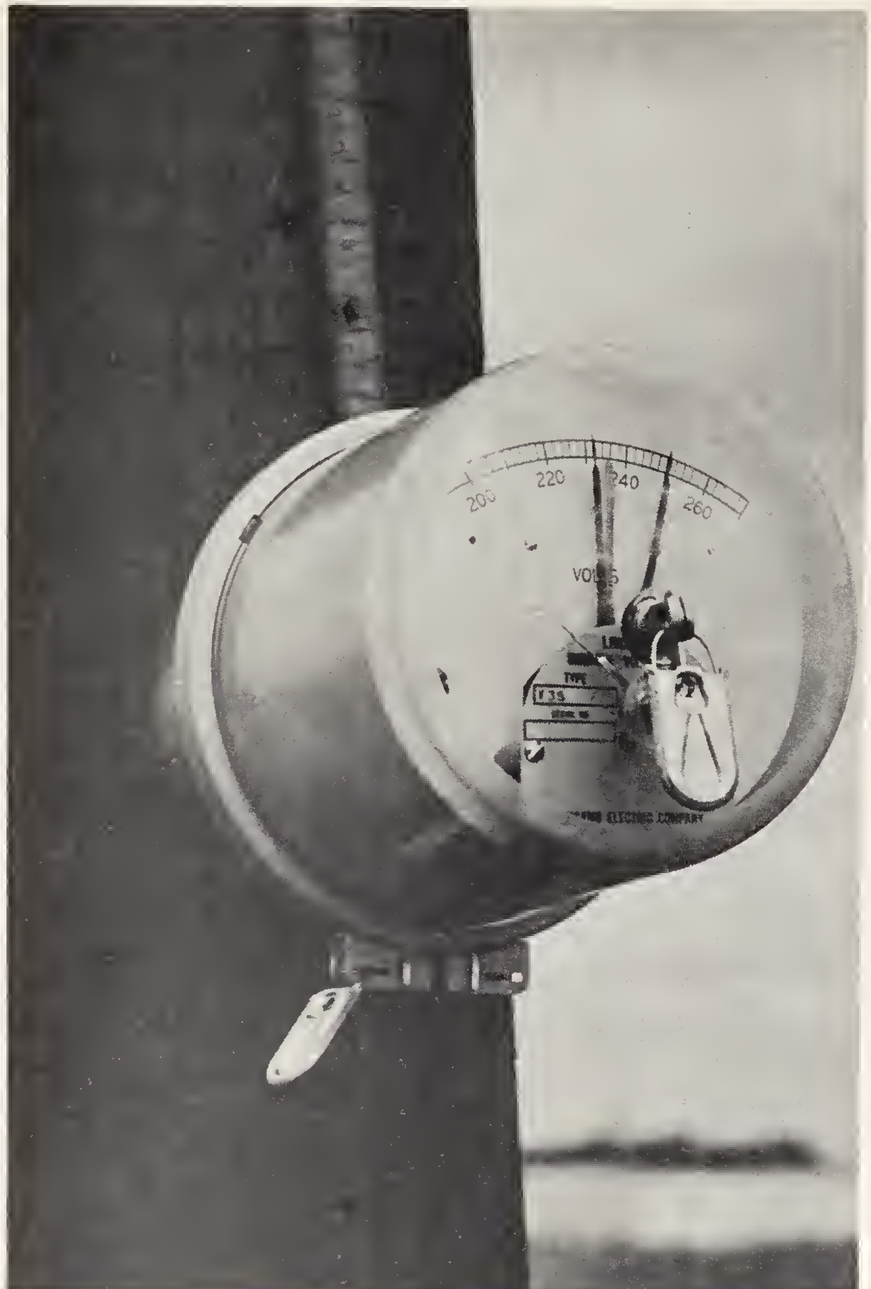

Figure 1 "MIN-MAX" Voltmeter Installed At End of Distribution Line

Figure 2 "MIN-MAX" Voltmeter and Ampere Demand Installed At Consumer's Meter Socket By Using Triple Socket Test Trough

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GUIDE FOR MAKING VOLTAGE MEASUREMENTS ON RURAL DISTRIBUTION SYSTEMS

By Roland W. Schlie
Electric Engineering Division

For Presentation at the Technical Conference for REA Field Engineers, Chicago, Ill., January 17-21, 1955

REA

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

GUIDE FOR MAKING VOLTAGE MEASUREMENTS ON RURAL DISTRIBUTION SYSTEMS

Roland W. Schlie

INTRODUCTION

Voltage conditions on a rural distribution system can not be evaluated unless the voltage levels have been accurately measured. Unless accurate voltage measurements are frequently obtained it is difficult, if not impossible, to maintain adequate voltage levels. Although numerous voltage complaints from consumers definitely prove that voltage levels are completely inadequate, the absence of consumer complaints is no indication of satisfactory voltage conditions on the system. Maximum benefit may be obtained from voltage measurements which have been made prior to the time consumer complaints are received.

INSTRUMENTS REQUIRED

Calibrating Standard

A voltmeter STANDARD should be available in the shop for the purpose of calibrating all instruments used for actual testing. Each distribution and transmission system should own a shop standard voltmeter. The meter may require calibration once in three years. The time interval between calibrations will depend upon the care and use of the meter. Calibration of a shop standard voltmeter may be obtained from a qualified testing laboratory or from the instrument manufacturer. These voltmeters should meet the following requirements:

1. The meter should have a stated accuracy of plus or minus one quarter of one percent of full scale.

2. The meter should not have been used for any test purpose except the calibration of test instruments since the last accuracy certification.

3. The meter should not have been transported except when packaged with extreme care, thus preventing any shock or vibration damage.

4. The meter should meet all the requirements of the American Standards Association standard for Electrical Indicating Instruments (C39.1-1951 or latest revision) having an accuracy class rating of 0.25 percent.

Service Instruments

At least two indicating voltmeters are recommended for conducting voltage measurements. Indicating voltmeters should have a stated accuracy of at least plus or minus three-quarters of one percent of full scale. Several recording voltmeters are also recommended for conducting voltage measurements. At least three of the instruments should have a stated accuracy of plus or minus one percent of full scale. In addition to these three precision instruments, additional instruments for general testing will be required. A thermal "min-max" voltmeter may be used for general testing. Since the minimum pointer of the "min-max" voltmeter does not respond to outages, voltage spread (minimum voltage minus maximum voltage) may be determined from the meter readings. Also, thermal ammeters may be used to determine circuit amperes from which voltage drop is calculated.

Test Voltage Source

A variable voltage source of relatively low capacity simplifies and greatly improves the accuracy of calibration tests. The variable voltage source is relatively inexpensive and has many general uses.

In some cases the supply voltage available for calibration tests will be subject to many rapid fluctuations or flicker. In these cases it is advisable to purchase a constant voltage source for calibrating tests. Care must be exercised in selecting a constant voltage source. The harmonic content of a constant voltage source should not exceed three percent.

Table I contains the suggested minimum test equipment for voltage measurements. Figures 1 through 8 are photographs of representative meters listed in Table I. A complete listing of all instruments is contained in the "List of Materials Acceptable for Use on Systems of REA Electrification Borrowers" under Section III, General Plant.

SUBSTATION MEASUREMENTS

Voltage measurements at the substation output are obtained by connecting the voltmeter to the potential test terminals located on the control panel of the regulator. Where three-phase regulators are used, the phase-to-neutral voltage of each phase can not be measured at the control panel. Usually the phase-to-neutral voltage can be measured at the potential transformers provided for the metering installation. In a few cases it may be necessary to provide the correct phase-to-neutral voltages by installing small distribution or potential transformers.

The high accuracy of the regulator control requires that voltage recordings be taken with a recording voltmeter that has a stated accuracy of at least plus or minus one percent of full scale. Changes in the control settings should not be made unless the voltmeter used to check the settings has been recently calibrated, at approximately the voltage being used, with the shop standard voltmeter.

Indicating voltmeters are used to check the balance and band width settings of the regulating relay. Indicating voltmeters used for this purpose should have a stated accuracy of at least plus or minus three-quarters of one percent of full scale.

Voltage recordings are required in order to check the line-drop compensator settings and the over-all voltage control. Usually a twenty-four hour recording of substation output voltage will supply the information required. Substation output voltage should be compared with substation kilowatt demand. Recorded output voltage should indicate that for the expected peak kilowatt demand the output voltage will be within the range of 124 to 127 volts. The readjustment of the line-drop compensator should be based upon accurate recordings of substation output voltage.

DISTRIBUTION PRIMARY LINE MEASUREMENTS

Primary Line Voltage Regulators

The output voltage of a line regulator is checked in the same manner as

substation output voltage is checked. The same voltage instrumentation should be used. The input voltage to a line regulator is treated as the end of a line.

Primary Line

Voltage measurements on the primary line are obtained by connecting the voltmeter to an unloaded distribution transformer, to a potential transformer, or to the potential test terminals located on the control panel of a regulator. Voltage evaluation is based upon voltage recordings rather than upon instantaneous voltage readings. Recording voltmeters used for this purpose should have a stated accuracy of at least plus or minus one percent of full scale.

Voltage drop is measured by using two recording voltmeters. One is located at the substation output while the other is located at the end of the distribution line or input to a line regulator. Simultaneous voltage recordings are taken for a twenty-four hour period.

Voltage drop is equal to the substation output voltage minus the voltage at the end of the line. The measured voltage drop corresponds to the load on the line when the measurement was taken. To make a complete evaluation of voltage drop conditions, both the measured voltage drop and the relative magnitude of load which existed at the time of measurement should be known. The relative magnitude of load may be estimated by assuming that the line load is proportional to the substation load. The voltage drop which may be expected on the line at some future date may be approximated by using the following formula:

$$\text{VD(Estimated)} = \text{VD(Measured)} \times \frac{\text{kw(Estimated)}}{\text{kw(Measured)}}$$

Where: VD(Measured) = The voltage drop determined from the voltage recordings.

kw(Measured) = The substation kw demand which occurred when VD(Measured) was determined.

kw(Estimated) = The substation kw demand which is estimated to occur at some future date.

VD(Estimated) = The estimated voltage drop which is expected to occur on the distribution line at the future date corresponding to kw(Estimated).

In this manner it is possible to approximate when a line is expected to become inadequate due to excessive voltage drop. Continuous evaluation of end-of-the-line voltages may also be desirable. Thermal type "min-max" voltmeters may be permanently installed at the ends of single-phase lines and minimum and maximum voltages periodically recorded.

Voltage drop measurements which are made at approximately the time of the system annual peak load will generally result in the more accurate evaluation of system maximum voltage drop conditions. Where the values of substation demands are not readily available, it may be desirable to install thermal demand ammeters in the neutral of the substation transformer bank. The values of ampere demands may then be used in the formula for approximating voltage drop. In some cases it may

be necessary to obtain ampere demands for the individual lines. The values of ampere demands may be readily obtained by installing thermal ampere demand meters in the individual lines.

DISTRIBUTION TRANSFORMER AND SECONDARY MEASUREMENTS

Measurements are taken at the meter socket to determine the voltage spread at the meter socket and the voltage drop through the distribution transformer and secondary conductor. Recording voltmeters or thermal type "min-max" voltmeters may be used to determine the voltage spread. Recording voltmeters used to check voltage spread should have a stated accuracy of at least plus or minus one and one-half percent ($\pm 1\frac{1}{2}\%$) of full scale within the normal operating range of the meter (110 to 130 volts or 220 to 260 volts).

The voltage drop through the distribution transformer and secondary conductor is most readily determined by calculation using the measured ampere demand at the meter socket. The maximum 30 minute ampere demand should be used. Recording ammeters or thermal type ampere demand meters may be used to determine the ampere demand. Recording ammeters used to determine the ampere demand should have a stated accuracy of at least plus or minus two percent of full scale.

One means of measuring the voltage spread and peak load amperes is illustrated in Figure 9. This metering installation consists of the following: (1) a triple socket test trough, (2) a three-wire thermal maximum demand ammeter, (3) a thermal type "min-max" voltmeter, and (4) the consumer's watthour meter. The consumer's watthour meter is removed from the standard socket and replaced by the triple socket test trough. The consumer's watthour meter and the two test instruments are then installed in the triple socket test trough. The test trough and meters are sealed in the usual manner.

Voltage spread is equal to the maximum voltage minus the minimum voltage which occurs during a 24-hour period. The maximum and minimum voltages are obtained from the recorded voltage or may be read directly from a "min-max" thermal type voltmeter. The voltmeter should be installed for a period of from four to seven days.

Voltage drop through the distribution transformer and secondary conductor is equal to the transformer primary voltage minus the voltage at the meter socket. Knowing the maximum load amperes, the corresponding voltage drop may be determined from Figures 10 through 13. The voltage drop through the distribution transformer is determined from Figure 10 for $1\frac{1}{2}$, 3, & 5 kva sizes and from Figure 11 for $7\frac{1}{2}$, 10, & 15 kva sizes. The voltage drop through the secondary conductor is determined from Figure 12 for load amperes up to 22.5 amps and from Figure 13 for load amperes up to 107.5 amps. For a specific installation, the total voltage drop is equal to the sum of the voltage drop through the transformer and the voltage drop through the secondary conductor. Additional data concerning Figures 10 through 13 is contained in the appendix.

APPENDIX

Explanation of Voltage Drop Figures

Voltage drop is equal to the sending-end voltage minus the receiving end

voltage. In certain cases it is not practical to measure both the sending-end voltage and the receiving-end voltage. This is true where it is necessary to determine the voltage drop through a distribution transformer, the secondary conductor, and the service conductor. It is relatively simple to determine the maximum current for a transformer and secondary installation. Figures 10 through 13 have been prepared to aid in calculating the voltage drop in transformer, secondary conductors, and service conductors when the maximum current has been determined by measurement.

The formula for the curves in Figures 10 and 11 is $VD = IZ$ where I is the load current in amperes measured at 240 volts, Z is the impedance of the transformer in ohms, and VD is the voltage drop at 240 volts. For convenience the Z curves are marked in percent values, rather than in ohms. The formula has been derived by making two assumptions; (1) the power factor of the load current is 0.9 and (2) the ratio of the transformer resistance to the transformer reactance is equal to 2.07. The formula is sufficiently accurate for load power factors between 0.80 and 1.0 and for resistance/reactance ratios between 1.5 and 3.5. These ratios are common for $1\frac{1}{2}$ through 15 kva distribution transformers.

The curves have been set up primarily for single-phase, three-wire, 120/240-volt transformer connections -- where the current is measured or calculated at 240 volts. For two-wire, 120-volt transformer connections where the current is measured or calculated at 120 volts, use the curves in the same manner but divide the measured current and the determined voltage by two. For single-phase, three-wire, 240/480-volt transformer connections where the current is measured or calculated at 480 volts, use the curves in the same manner but multiply the measured current and the determined voltage by two. For three-phase, three-wire, delta transformer connections where the current is measured or calculated as the amperes per phase, the voltage drop will be the phase-to-phase drop. For three-phase, four-wire, wye transformer connections where the current is measured or calculated as the amperes per phase, the voltage drop will be the phase-to-neutral drop.

The formula for Figures 12 and 13 is $VD = ISK$ where I is the current in amperes, S is the circuit distance in feet, and K is the wire constant. The wire constant, K, is equal to $2R \cdot \cos \theta$ plus $2X \cdot \sin \theta$ where R is the resistance per foot, X is the reactance per foot and $\cos \theta$ is the load power factor. The curves are constructed for $\cos \theta$ equal to 0.9. The formula is sufficiently accurate for load power factors between 0.8 and 1.0.

The values of K are practically the same for spacings between eight inches and eighteen inches. The solid curves for each wire size are calculated for twelve-inch spacing. The value of K for cable type conductors such as service entrance cable, "Triplex" conductor, and conductors in conduit are different than for standard spaced conductors. The dotted curves for each wire size of cable type conductor are figured for approximately 3/8 inch spacing. The curves are based on single-phase, three-wire, balanced circuits. For balanced three-phase circuits where the current is equal to the amperes per phase; (1) divide the voltage drop by two for the phase-to-phase drop and (2) multiply the voltage drop by the square root of three divided by two for the phase-to-neutral drop.

Following are two examples illustrating the use of Figures 10 through 13.

Example No. 1:

Given: Three kva transformer, 2.8% transformer impedance, secondary and service conductor length - 475 feet, and secondary and service conductor size - #6 copper.

Measured current at the meter socket at 240 volts is a maximum of 15.5 amperes.

The transformer voltage drop is obtained from Figure 10 (3kva). Enter the ampere scale at 15.5 amperes, continue horizontally to the right to intersect the transformer impedance curve (2.8%), read the intersection of the ampere scale and the transformer impedance curve on the voltage drop scale. The voltage drop for this example is 8.4 volts.

The secondary and service voltage drop is obtained from Figure 12. Enter the ampere scale at 15.5 amperes, continue vertically upward to intersect the circuit-length curve (475 ft.), continue horizontally to the right to intersect the wire-size curve (6), continue vertically downward to intersect the voltage drop scale. The voltage drop for this example is 6.2 volts. The transformer drop plus the secondary and service drop is 8.4 plus 6.2 or 14.6 volts.

Example No. 2:

Given: Ten kva transformer, 2.6% transformer impedance, secondary and service conductor length - 150 feet, secondary and service conductor size - 1/0 "Triplex" which is #2 copper equivalent.

Measured current at the meter socket at 240 volts is a maximum of 52.5 amperes.

The transformer drop as determined from Figure 11 is 7.8 volts. The secondary and service conductor drop as determined from Figure 13 is 2.4 volts. The total voltage drop is equal to 7.8 plus 2.4 or 10.2 volts.

REFERENCES

1. REA Bulletin 169-2
System Voltage Limits for Satisfactory Television Receiver Operation

2. REA Bulletin 169-3
Voltage Evaluation and Voltage Improvement of Rural Distribution Systems

3. REA Bulletin 169-4
Voltage Levels on Rural Distribution Systems

4. REA Bulletin 169-27
Voltage Regulator Application on Rural Distribution Systems

TABLE I

SUGGESTED MINIMUM TEST EQUIPMENT
FOR
VOLTAGE MEASUREMENTS

ITEM	MINIMUM NUMBER REQUIRED	DESCRIPTION
Voltmeter	1	Shop Standard
Voltmeter	2	Indicating Instrument for Precision Testing
Voltmeter	3	Recording Instrument for Precision Testing
Voltmeter	3	Recording Voltmeter or Indicating Thermal Type for General Testing
Ammeter	4	Recording Ammeter or Indicating Thermal Type for General Testing
Voltage Source	1	Variable Voltage Source for Testing and Calibrating

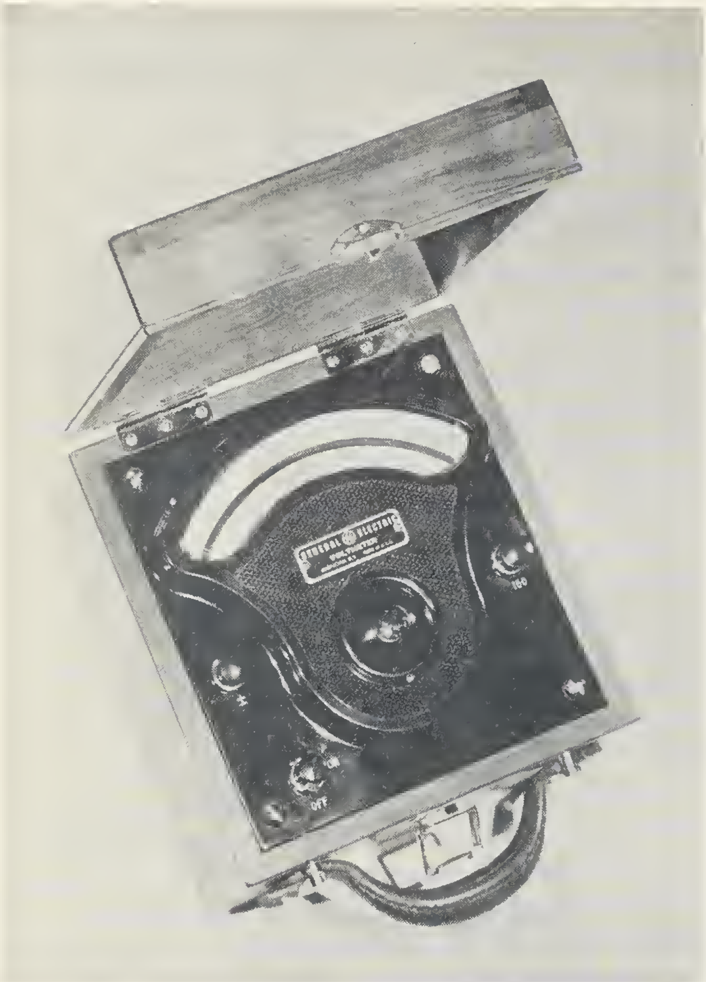

Figure 1. SHOP STANDARD - General Electric Company, Type P3, AC Voltmeter

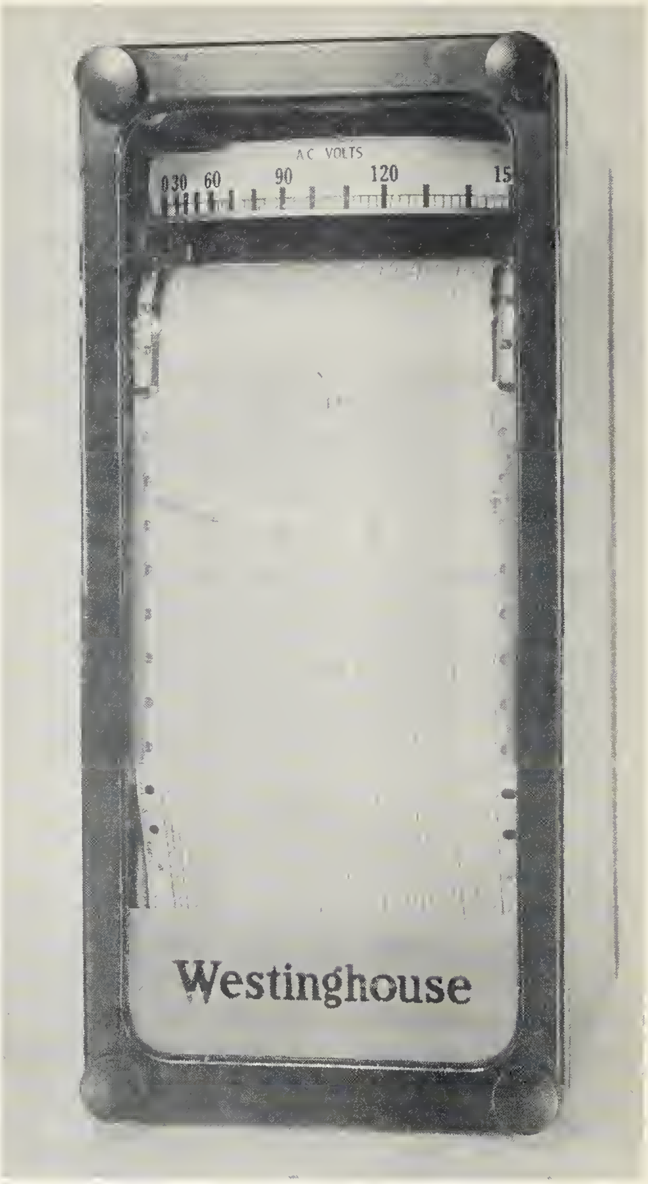

Figure 2. INDICATING VOLTMETER - For General Testing - Weston Electrical Instruments Company, Model 433, AC

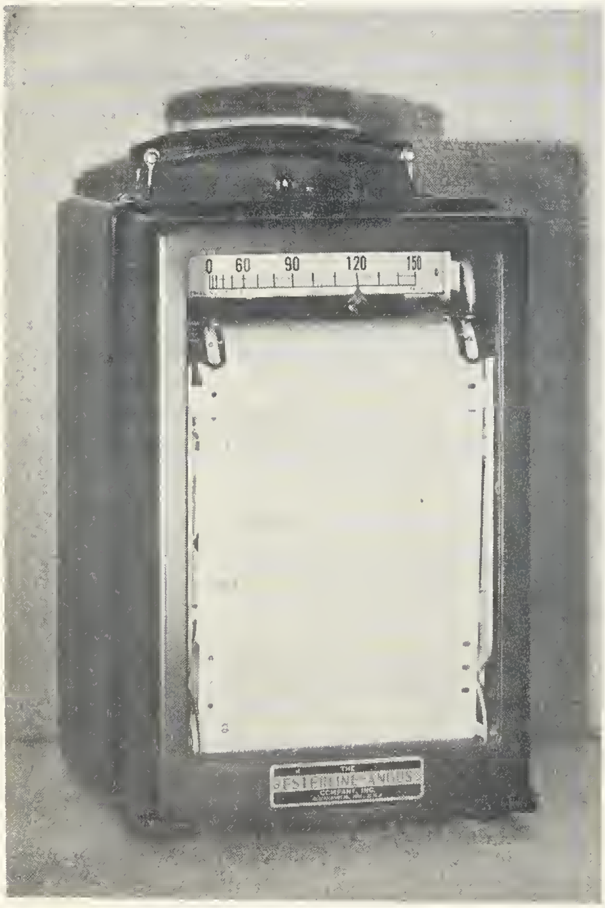

Figure 3. RECORDING VOLTMETER - For Precision Testing - Esterline-Angus Company, Model AW, AC

Figure 4. RECORDING VOLTMETER - For Precision Testing - Westinghouse Electric Corporation, Model GY-40, AC

Figure 5. THERMAL TYPE VOLTMETER - For General Testing - Sangamo Electric Company, Type V3S

Figure 6. THERMAL TYPE AMMETER - Three-Wire - For General Testing - Sangamo Electric Company, Type ADS-3W

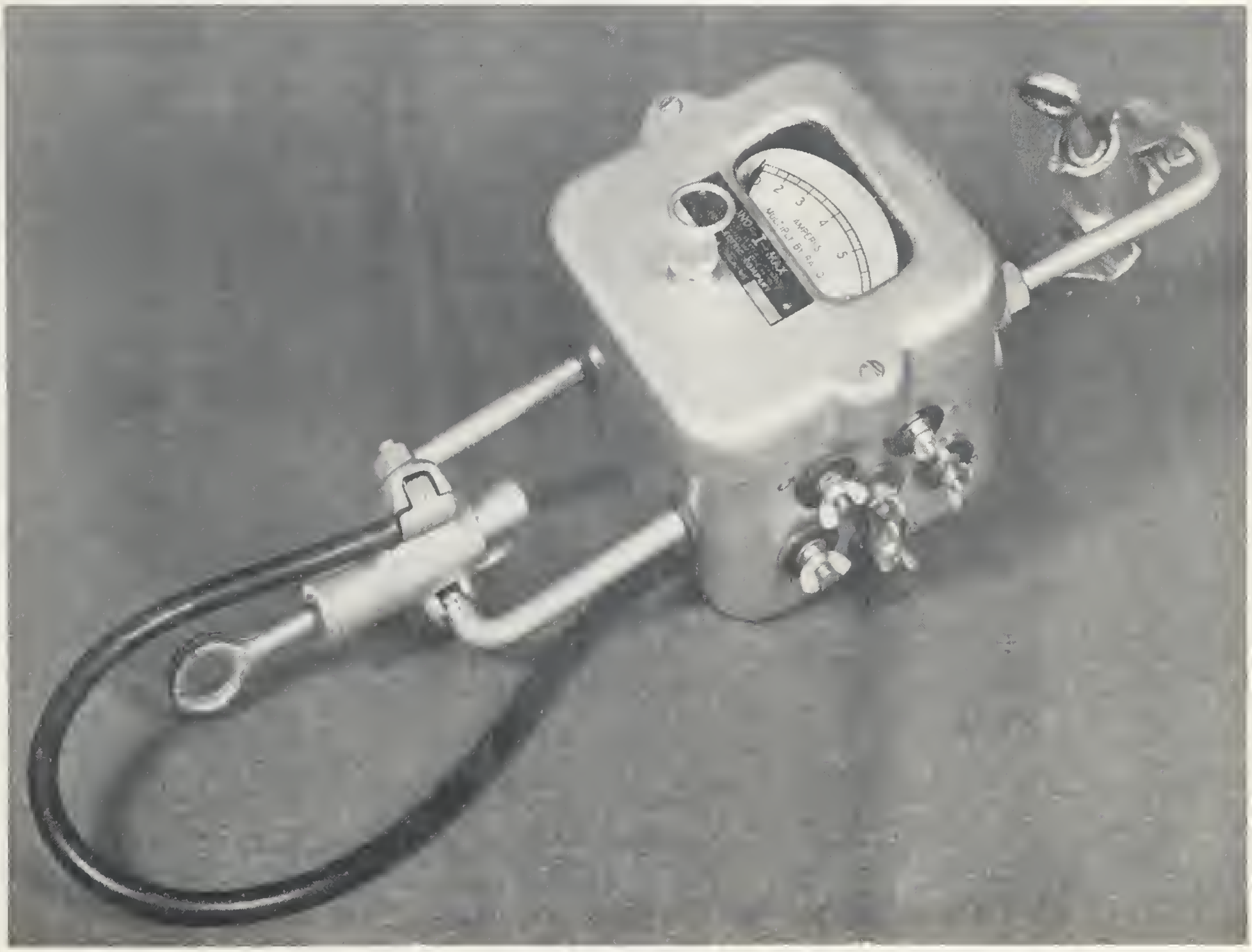

Figure 7. THERMAL TYPE AMMETER - For General Testing - HD Electric Company, "IND-I-MAX"

Figure 8. VARIABLE VOLTAGE SOURCE - Superior Electric Company, Powerstat, Type 116

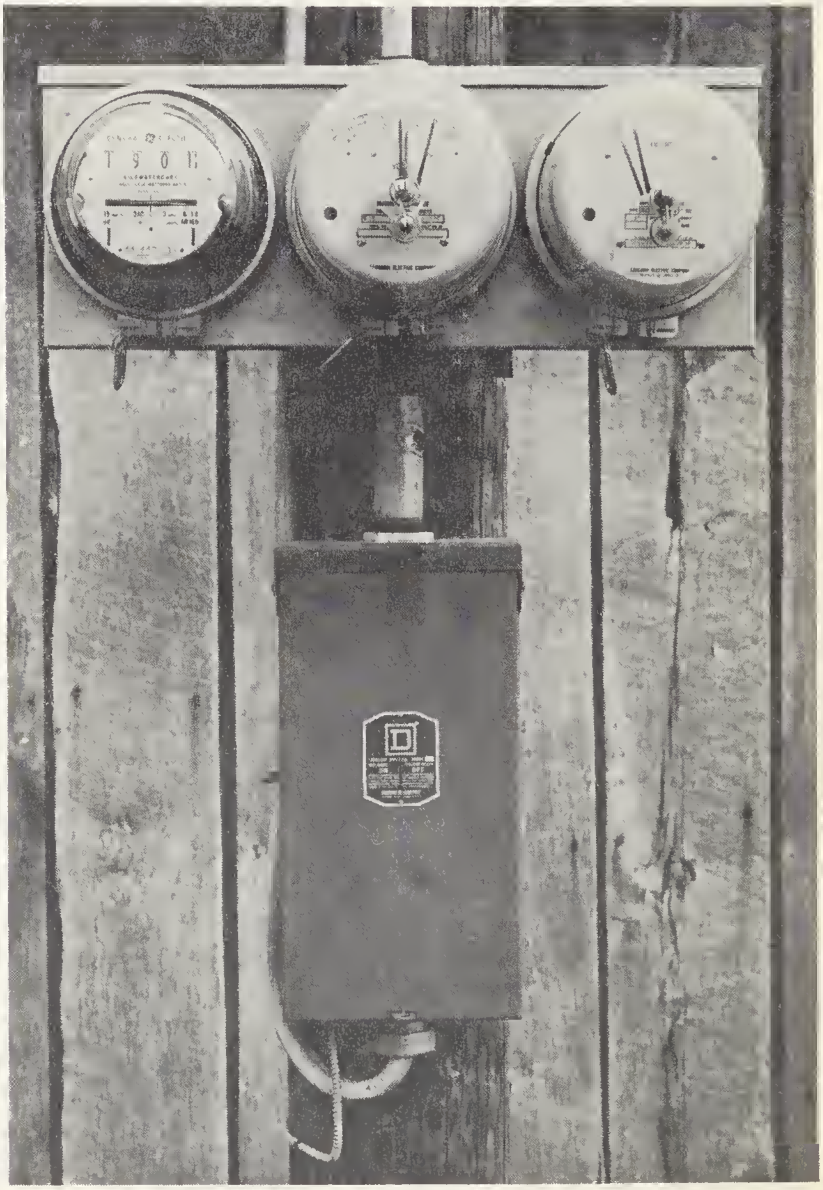

Figure 9. THREE SOCKET TEST TROUGH & METER INSTALLATION

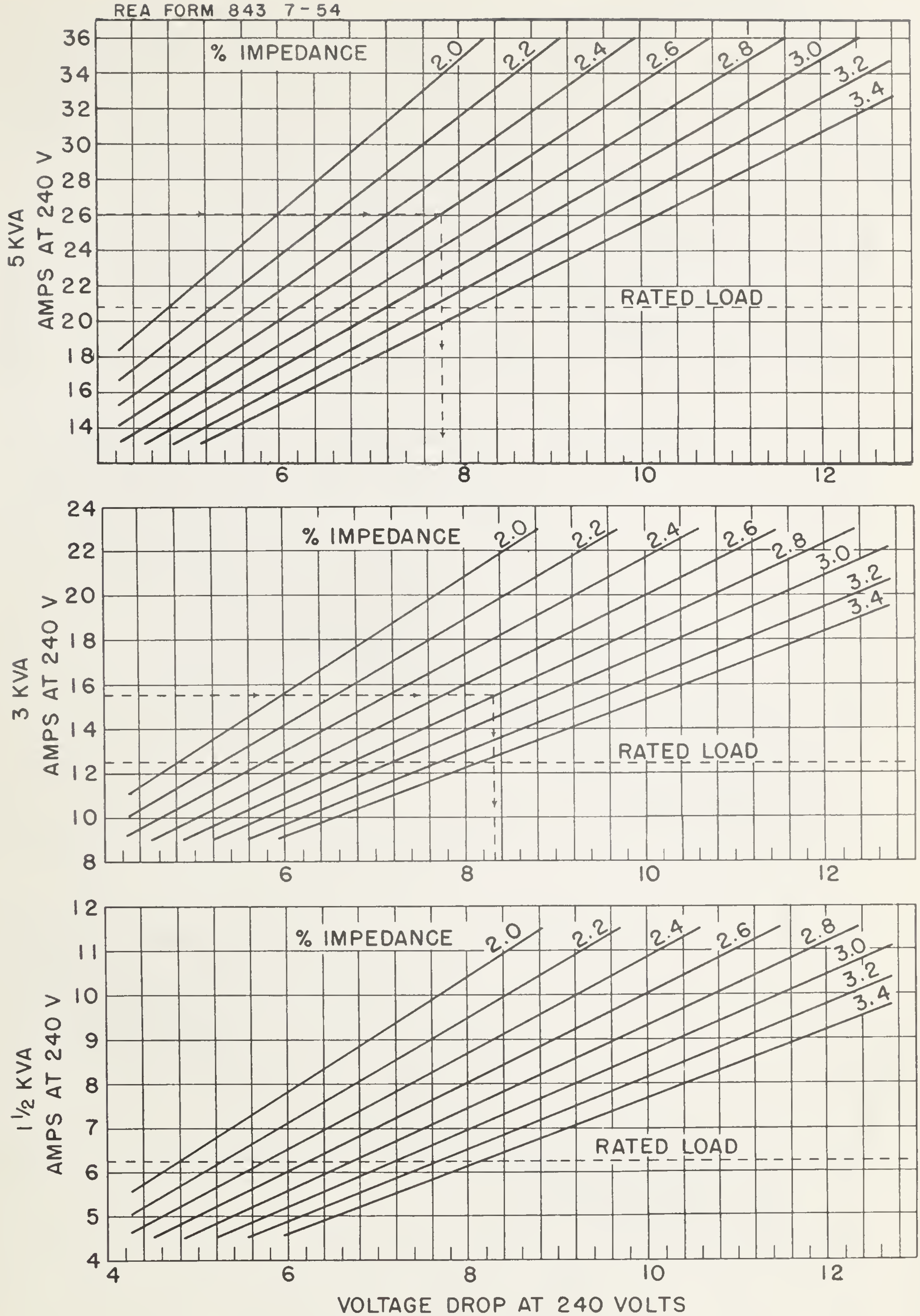

Figure 10. TRANSFORMER VOLTAGE DROP,
$1\frac{1}{2}$, 3 & 5 kva Sizes

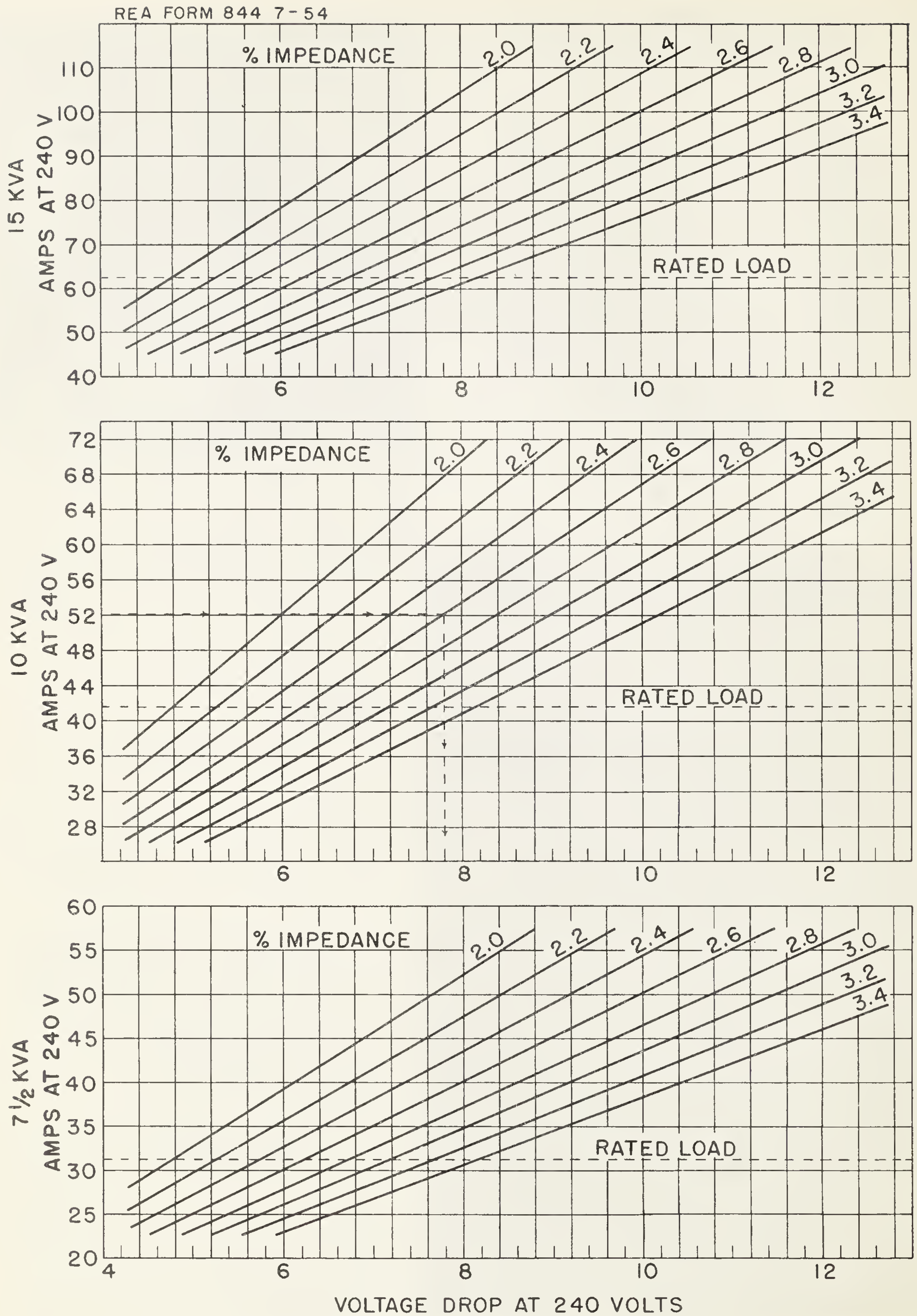

Figure 11. TRANSFORMER VOLTAGE DROP,
$7\frac{1}{2}$, 10 & 15 kva Sizes

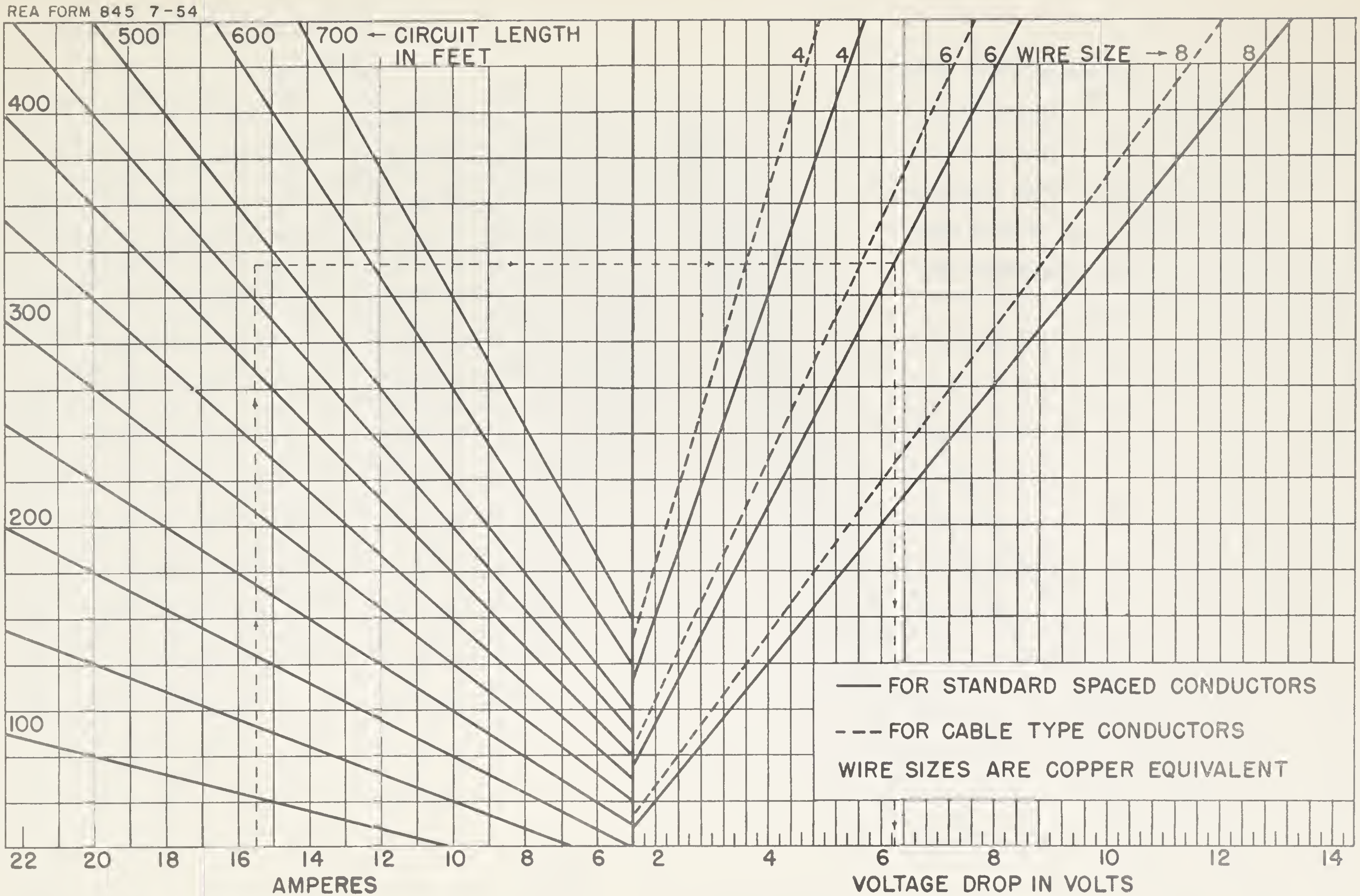

Figure 12. SECONDARY & SERVICE VOLTAGE DROP,
5 to 22.5 Amperes

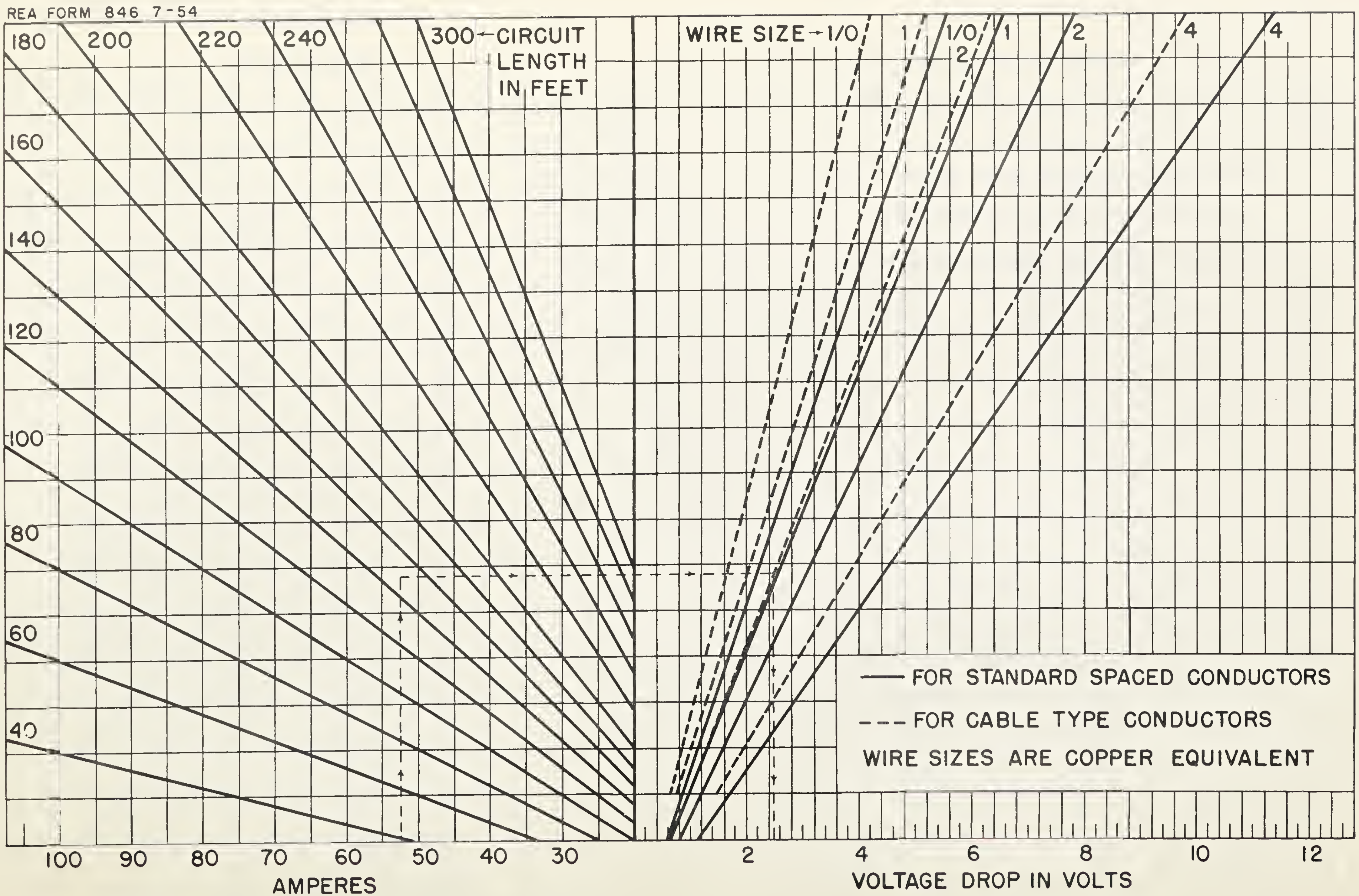

Figure 13. SECONDARY & SERVICE VOLTAGE DROP, 20 to 107.5 Amperes

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SELECTION OF METERING FOR WIDE RANGE APPLICATION

By Harold W. Kelley
Electric Engineering Division

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
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RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

SELECTION OF METERING FOR WIDE RANGE APPLICATION

Harold W. Kelley

INTRODUCTION

In order to understand the basis for the general application of watthour meters, let us briefly review the design parameters for these devices. The watthour meter consists of the following major components:

1. A current coil and its associated electromagnetic circuit.

2. A potential coil and its associated electromagnetic circuit.

3. A rotating disk and its bearings and guides.

4. A magnetic braking system with supports and adjustments.

5. A counter, or register, for totalizing the revolutions of the disk.

6. A housing or frame for supporting the various parts of the meter and providing terminals for connections to the electrical circuit.

An examination of the above listing indicates that any one manufacturer can establish its own requirements as to current rating, ampere-turns and flux density in the current electromagnetic circuit, potential coil rating, ampere-turns and flux density in the potential electromagnetic circuit, disk rotational speed for rated load, location and loading of the bearing system, strength and location of the permanent magnets used for braking, general design of the housing, terminals and cover. As the above design parameters are closely interrelated, the selection of some automatically determine the limits of the others. Let us suppose a manufacturer decides that 30 rpm is a good compromise for rated load speed for its 240 volt, 15 ampere, 3 wire, meter. This automatically establishes the gear ratio to be used on the meter. However, the manufacturer still has the choice of how the total is divided between the register and the reduction-at-shaft gearing.

For many years, each manufacturer designed and produced meters with little or no coordination with the other manufacturers of similar devices. Consequently, there have been hundreds of different current ratings, speeds, and other variables that are related to these factors. After 1925, there appeared to be a trend toward standardization of watthour meters, affecting primarily the current ratings. By 1930, practically all current ratings were dropped with the exception of 15 and 50 amperes in self-contained meters and 2.5 and 5.0 amperes in transformer rated meters.

Table I and Table II illustrate the variations between manufacturers in the design of single-phase meters. These tables cover meters manufactured since 1936. You will note the trend toward standardization in Table II. The meters covered by this table are of new design and represent the latest models to be placed in production. Some of these meters were made available for the first time as late as two months ago.

If you examine the two tables, you will note there is no indication of current capability of the meters, except the nameplate rating in amperes. As we have stated, this rating is a design value to establish the rated speed and has no direct connection with the maximum load capability of the meter. After a watthour meter has been designed, a heat run on coils and terminals plus an extended load accuracy test reveals the maximum continuous loading permissible. The watthour meter is unique in the electrical industry in that the nameplate rating is not the continuous service capability.

Over a period of years, improved design, better materials and manufacturing methods have contributed to increased load capability for the standard ratings of the meters. The following tabulation indicates the increasing spread between nameplate and maximum loading capacity for the standard 15 ampere meter used for domestic service:

Design	Maximum Continuous Load to Stay Within 1/2%	
Year	Percent of Rated Current	Amperes
1910	120	18.0
1924	150	22.5
1934	300	45.0
1940	400	60.0
1954	667	100.0

APPLICATION OF SELF-CONTAINED WATTHOUR METERS

In the past, the rural cooperatives have been primarily concerned with the correct application of self-contained watthour meters for farm and home service. In order to better understand the capabilities of these meters, let us extend the information contained in the previous table:

Capability of 3 Wire, 240 Volt, Single-phase Watthour Meters

Design	Ampere	Maximum Continuous Load Not to Exceed Thermal and 1/2% Accuracy Limits			
Year	Rating	% Nameplate	Amperes	KVA	Socket
1940	15	400	60	14.4	Std.
1954	15	667	100	24.0	Std.*
1940	50	300	150	35.0	HD.
1954	50	400	200	48.0	HD.

*Standard jaws with terminals for adequate wire size.

You will immediately notice that maximum capacity of the 50 ampere single-phase meters has not kept pace with that of the 15 ampere rating. This has not been a

design flaw in the 50 ampere series; but, is the result of previous design standardization of the socket type meter terminals and socket jaws. Although the 50 ampere meters are capable of handling loads above 200 amperes, the heat created at the junction of the socket jaw and meter blade has restricted the loading to 200 amperes and below. On the other hand, "A" base, or bottom connected, meters suffer from the same difficulty---connections and terminals are standardized to such extent that space is not available to handle capacity beyond 200 amperes on the most conservatively designed meter. This is not a serious problem as adequate alternates have been made available. We will explore that phase later in the discussion of transformer type metering.

As a general guide, 15 ampere meters produced before 1954 are adequate for 60 ampere services; those produced today are adequate for 100 ampere services. For services between 100 amperes and 200 amperes, the 50 ampere self-contained meter (or its equivalent) is satisfactory. <u>In no case, should the 50 ampere meter be installed in a standard capacity meter socket.</u> The almost certain result is a burned out meter caused by heating at the meter terminals. If the extra expense of the high capacity meter is warranted, it is only common sense to install the meter in a socket capable of handling the load.

We referred to the 50 ampere meter, or its equivalent. Present information is that the Westinghouse Electric Corporation will not manufacture a 50 ampere watthour meter in the Type D series. As the 15 ampere, Type D, meter has 667% load capability, Westinghouse has determined that a 30 ampere meter with the same (667%) loading capability will be satisfactory for 200 ampere loads. We feel the 30 ampere, Type D, watthour meter is equivalent to those labeled as 50 ampere rating by other manufacturers.

Figure 1 illustrates the general design of jaws and terminals of the standard duty watthour meter socket. The jaws are of spring bronze, generally silver plated. Practically all sockets of this class use either Westinghouse or Duncan manufactured jaws. The terminals of this socket are capable of taking #4 stranded conductor, limiting the circuit capacity to a maximum of 50 amperes.

Figure 2 shows the same jaw assembly with lay-in terminals that will take wire sizes up through #1/0 or #2/0. Because of the jaw capacity, this combination is limited to 100 amperes maximum loading.

Figure 3 illustrates the medium duty jaw assembly. This design is offered by several manufacturers for service loads to approximately 150 amperes. This device is satisfactory for use with 50 ampere meters where the full 200 ampere capability of the meter is not needed or for other reasons cannot be used.

Figure 4 is the heavy duty jaw assembly, rated for full 200 amperes. This unit is designed specifically for 50 ampere meter installation. This assembly is manufactured by the Duncan Electric Manufacturing Company and is sold by several manufacturers. It has become the standard for heavy duty metering. You will note the major departure from the spring loaded jaw design of the standard socket. The cap screws on the clamp type jaws permit high pressure contact with considerable contact area. Expansion coefficients have been worked out to eliminate loss of pressure during the thermal cycle. This design has recently been made available for polyphase meter installations.

On services above 60 amperes, the secret of a good installation is simple: Use generous wire capacity to carry the heat away from the meter jaws and terminals. The radiation area in the vicinity of the watthour meter base is extremely restricted. There is practically no ventilation to assist in heat dissipation. The main problem is to get the heat out of the socket so it can be dissipated in the air. Large service conductors, plus the conduit exposure, is about the only way this can be done short of forced draft ventilation. Although we might be able to drop wire size in the meter loop portion of the service run without materially adding to the voltage drop, resorting to such practice would endanger the capacity of the whole installation. Reduced conductor size would run at elevated temperatures and would not act as a heat sink to the meter socket assembly. Manufacturers are very careful to rate the meter sockets in such a manner that the rating is associted with wire and conduit size.

APPLICATION OF TRANSFORMER-RATED WATTHOUR METERS

Although manufacturers have extended the load ranges for self-contained watthour meters, some rural loads have become too large to meter by simple installation of a self-contained meter and socket. Typical of such loads are motels, roadside restaurants, small factories, cotton gins, sawmills, and irrigation pumps. Regardless of the number of phases used to serve such loads, the problem remains the same: Instrument transformers must be used to bring the currents and potentials down to a level that can be safely and accurately metered.

When is it necessary or preferable to use instrument transformers to meter a load? This may be answered by the following listings:

Instrument transformers are necessary when,

1. Load currents exceed the maximum 200 amperes allowed for self-contained meters, then current transformers are required.

2. Load potentials exceed 600 volts, then potential and current transformers are required.

Instrument transformers are preferable when,

1. Load currents on a constant load exceed approximately 150 amperes, even though the potential is 240 volts or less, then current transformers are recommended.

2. Load potentials exceed 240 volts, then potential and current transformers are recommended.

There is no question as to requiring use of current transformers on loads above 200 amperes. It is the only way the load can be metered. Although installation of a 50 ampere meter and heavy duty socket is adequate for load currents of 150 amperes, to make such an installation when the load is at this level does not give one much room for load growth. As there is little cost difference on single-phase installations, it is generally recommended that the transformer installation be made.

Watthour meters are manufactured with potential ratings from 120 volts through 550 volts. Manufacturers are aware that potential coils above 240 volts are subject

to high failure rates. One manufacturer's* booklet states it as follows: "These increased failures in the ratio of about 3 to 1 (440 volt vs. 120-240 volt) are due principally to the fact that 440 volts is higher than the critical value of 308 volts, above which power-follow arcing will generally take place as previously described, due to sustained ionization of the conducting gap." In other words, if there is an arc formed in a meter operating below 308 volts, the arc extinguishes itself when the arc current goes through zero at the end of the half-cycle. As the potential is not high enough to keep the gap ionized, there is no restriking of the arc and generally no serious damage. If a similar arc is formed in a meter operating at 440 volts or 550 volts, it does not extinguish itself and continues burning metal and insulation until the meter is destroyed or the supply circuit is interrupted. An examination of the remains of this type of failure generally shows that nothing can be salvaged--the meter is a total loss. This is basically why it is recommended that potential transformers be used on circuits above 240 volts.

As we will definitely be required to transform load currents and potentials to smaller values so they can be handled in metering circuits, let us examine the characteristics of the transformers in relation to those of the meters. We have shown in previous discussion that watthour meters are capable of handling currents considerably higher than the nameplate rating. In fact, the 2.5 ampere meter for transformer service is capable of 400% constant loading. This is not true of current transformers. EACH CURRENT TRANSFORMER MUST BE APPLIED IN ACCORDANCE WITH THE RECOMMENDATIONS OF THE MANUFACTURER. There are some current transformers that maintain accuracy and remain within thermal limits at 200% of nameplate rating, others are limited to 150% of nameplate, while the majority (especially the high voltage designs) are limited to 100% of the nameplate rating. This point cannot be overemphasized: Under no conditions attempt to apply a current transformer on an overload basis unless specifically recommended by the manufacturer.

For many years, the secondary current rating of current transformers has been 5 amperes. Watthour meters for use with these transformers have been 2.5 amperes. Because of the excellent overload characteristics of the watthour meter, the combination of these two devices in a metering installation has resulted in high accuracy over a wide range of load. We have shown that the current transformer is very limited in its overload characteristics; on the other hand, the watthour meter has a wide overload range but shows inaccuracies in the extreme light load zone--below 5% rated load. By making maximum load on the meter equal to 200% or 400% of the nameplate rating, the service load can drop to 5% of its maximum value and still leave the watthour meter operating on 10% or 20% of its nameplate rating, well out of the inaccurate zone. The 400% loading on the meter can only be accomplished by use of a current transformer capable of continuous loading at 200% of its nameplate rating, i.e., 10 amperes maximum secondary current (which equals 400% load on a 2.5 ampere meter).

Most of our applications of current transformers will be in the service voltage class (600 volts and below). Until recently, there were hundreds of type of current transformers available for this service. Both the indoor and outdoor units were expensive. Within the past two years, manufacturers have developed a line of current transformers ideally suited to practically all installation needs. These may be called by various names: "butyl-molded", "rubber-coated", "plastic-molded", "service through-type", "indoor-outdoor", etc. This series of transformers is actually a through-type (doughnut) transformer of the single turn primary type suitable for all-weather mounting on services up to 600 volts.

These through-type transformers have certain characteristics which must be understood if they are to be correctly applied to metering circuits.

1. The transformers are designed basically for single meter burdens. Although they may carry as many as two instruments or meters at one time, the secondary current circuit length must be very short.

2. The transformers are generally safe to use without shorting test switches as they saturate at a low secondary voltage (approximately 80 volts or less). In spite of manufacturers' recommendations on this point, it is preferable to handle these transformers with the same precautions as those that produce dangerous voltages.

3. As the burden capability of these transformers is very limited, the length and spacing of secondary runs is likewise restricted. Where the meter is at the base of the pole on which the transformer is mounted and where the secondary is in conduit or cable, there is no problem of circuit length. Caution must be exercised where meters are more remote to the transformer. It is suggested that manufacturers be consulted where long runs are necessary.

4. The transformers are designed for loadings up to 200% of the nameplate ratings. The accuracy and thermal limits are not affected by loading to this level.

Figure 5 illustrates some of the through-type transformers now available. You will note that bases are removable, mountings can be had for pole or flat surface installations. The following table is a partial list of the manufacturers and types offered:

Manufacturer	Type	Ampere Ratings	Maximum Loading
Allis-Chalmers	Type TWM	200, 400, 600	200%
Allis-Chalmers	Type TWM	800	150%
General Electric	Type JCA-0	200, 400	200%
General Electric	Type JKP-0	200, 400, 600, 800	200%
Sangamo	Type R	200, 400	200%
Westinghouse	Type FWO	200, 400, 600, 800	200%

The above transformers have practically replaced the majority of the various types of indoor and outdoor transformers on services below 600 volts. As they are available with various combinations of mounting bases and primary bars, they can be used for replacement of the older types now in service.

REA has recognized the advantages of the new designs. We are now converting some of the older metering guide drawings to conform to the newer devices. As a result of this trend, you will find little or no application of the metering assembly having indoor current transformers in a weatherproof box (DWG M8-2). The outdoor

transformers simplify both single-phase and three-phase installations. Recently accepted drawings: A 3589 (M8-6); A 3590 (M8-7), and A 3591 (M8-8) show some of the changes and improvements made by use of these transformers.

Examination of (M8-6) and (M8-7) reveals that transformers on the single-phase, or lighting, leg of the service are mounted in a vertical position. This was done to prevent awkward looping when the transformer is used as a three-wire transformer. The vertical mounting permits direct feed-through for both service wires, the reversal of one is achieved by feeding through the opposite end of the transformer. It must be kept in mind that the transformer ratio (as marked on the nameplate) must be twice the multiplying ratio when used as a three-wire transformer.

You will observe that the top wire in (M8-7) is marked as Neutral while the title shows Three-Phrase, Three-Wire Service. Both identifications are correct. This drawing is designed specifically for three-phase services such as you encounter on irrigation wells, oil wells, etc., where <u>no</u> lighting circuit is required. The three-phase service is actually <u>grounded</u> <u>phase</u> delta, having the top phase (marked as Neutral) grounded to primary neutral and grounding connections at the transformer bank. This connection requires that all center taps on the transformers be isolated from ground by removing the grounding strap. This type service conforms to Code requirements and offers several advantages over the center-tap grounding of one transformer. These advantages are:

1. The <u>grounded</u> <u>phase</u> has to be identified (may be bare conductor)throughout its length but can be used as the interconnecting grounding conductor. This establishes interconnection of primary and secondary grounds without running a fourth wire. The grounding conductors from motor starters, etc., must be a <u>fourth</u> wire from the line side of the starter.

2. Provides a grounded service with maximum voltage (phase-to-phase) from ground to "hot" phase wires. This improves fuse coordination on ground faults.

3. Prevents possibility of current diversion. A driven ground to a light bulb connection on the center tap type ground would provide lighting (if the circuit were 240 volts phase-to-phase) with improper metering. The grounded phase operation provides proof against this connection and allows the use of a two element meter at all times.

4. If lightning protection is required, only two arrester elements are needed. This connection actually reduces the possibility of lightning damage as it establishes an interconnection of grounds and keeps the surge potential differences to a minimum.

It is suggested that you encourage the REA cooperatives to look into the advantages of transformer type services where such services could be used in lieu of the heavy duty type self-contained services. If the service load is such as to require a 50 ampere meter and heavy duty socket (indicating loads between 100 and 200 amperes) there may be little room for future load growth. Where the cooperative supplies the meter loop, there is little cost differential in the two type of services---with a large advantage going to the transformer type service because of its ability to

handle considerable load growth. Even if the load is not up to 200 amperes, the through-type transformer can be double looped to provide a 100 ampere service that can be left practically intact until the load exceeds 400 amperes. The only change required, providing the wire size is adequate, is to change the transformer (200:5) from the double loop primary (making it 100:5) back to single loop for full 200 ampere service with 200% nameplate capability. Throughout this wide range of load, the meter will provide high accuracy and be in no danger of overheating.

CONCLUSIONS

Present-day metering equipment, if properly applied, can provide many years of service without becoming obsolete because of load growth. Improperly applied, it can become an appreciable item in the cost of operations because of frequent changeouts to prevent over loading.

As a general rule, the most recent line of meters of 15 ampere rating are adequate for farm and home service through 100 amperes capacity. Meters of the 50 ampere rating, installed in heavy duty bases with adequate wire size, are adequate for 200 amperes capacity. However, where the initial load level approaches the limit of the meter there is no allowance for future load growth. Under these circumstances, the next larger type service should be installed.

It is suggested that cooperatives standardize on through-type current transformers for transformer type metering on circuits below 600 volts. Most of the cooperatives should purchase 200:5 and 400:5 ampere ratings as standard units. These two ratings will handle all loads from 100 amperes through 400 amperes, which should cover practically all loads found in rural areas.

TABLE I

SPECIFICATION DATA ON WATTHOUR METERS
(Single-phase Meters of Recent Manufacture)

Manufacturer	Type	Design Speed RPM	Design Speed RPH	Meter Rating Volts	Meter Rating Amperes	K_h	Number of Teeth 1st. Reg. Gear	Number of Teeth Disk Shaft	Reduction at Shaft Ratio	Register Ratio R_r	Register Constant K_r
Duncan	MF	30	1800	120	2.5	1/6	75	1	75:1	800	1
Duncan	MF	30	1800	120	5	1/3	75	1	75:1	400	1
Duncan	MF	30	1800	120	15	1	75	1	75:1	133 1/3	1
Duncan	MF	30	1800	240	2.5	1/3	75	1	75:1	400	1
Duncan	MF	30	1800	240	5	2/3	75	1	75:1	200	1
Duncan	MF	30	1800	240	15	2	75	1	75:1	66 2/3	1
Duncan	MF	30	1800	240	50	6 2/3	75	1	75:1	200	10
General Elec.	I-30	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
General Elec.	I-30	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
General Elec.	I-30	16 2/3	1000	120	15	1.5	100	1	100:1	66 2/3	1
General Elec.	I-30	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
General Elec.	I-30	16 2/3	1000	240	5	1.2	100	1	100:1	83 1/3	1
General Elec.	I-30	16 2/3	1000	240	15	3.0	100	1	100:1	33 1/3	1
General Elec.	I-30	16 2/3	1000	240	50	12.0	100	1	100:1	8 1/3	1
General Elec.	I-30	16 2/3	1000	240	50	12.0	100	1	100:1	83 1/3	10
Sangamo	J	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
Sangamo	J	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
Sangamo	J	16 2/3	1000	120	15	1.8	100	1	100:1	55 5/9	1
Sangamo	J	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
Sangamo	J	16 2/3	1000	240	5	1.2	100	1	100:1	83 1/3	1
Sangamo	J	16 2/3	1000	240	15	3.6	100	1	100:1	27 7/9	1
Sangamo	J	16 2/3	1000	240	50	12.0	100	1	100:1	8 1/3	1
Sangamo	J	16 2/3	1000	240	50	12.0	100	1	100:1	83 1/3	10
Westinghouse	C	30	1800	120	5	1/3	100	12	8 1/3:1	3600	1
Westinghouse	C	30	1800	120	15	1	100	12	8 1/3:1	1200	1
Westinghouse	C	30	1800	240	2.5	1/3	100	12	8 1/3:1	3600	1
Westinghouse	C	30	1800	240	5	2/3	100	12	8 1/3:1	1800	1
Westinghouse	C	30	1800	240	15	2	100	12	8 1/3:1	600	1
Westinghouse	C	30	1800	240	50	6 2/3	100	12	8 1/3:1	180	1
Westinghouse	C	30	1800	240	50	6 2/3	100	12	8 1/3:1	1800	10

TABLE II

SPECIFICATION DATA ON WATTHOUR METERS
(Single-phase Meters of Latest Design and Currently in Production)

Manufacturer	Type	Design Speed RPM	Design Speed RPH	Meter Rating Volts	Meter Rating Amperes	K_h	Number of Teeth 1st. Reg. Gear	Number of Teeth Disk Shaft	Reduction at Shaft Ratio	Register Ratio R_r	Register Constant K_r
Duncan	MK	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
Duncan	MK*	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
Duncan	MK	16 2/3	1000	120	15	1.8	100	1	100:1	55 5/9	1
Duncan	MK	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
Duncan	MK	16 2/3	1000	240	15	3.6	100	1	100:1	27 7/9	1
Duncan	MK	16 2/3	1000	240	50	12.0	100	1	100:1	8 1/3	1
Duncan	MK	16 2/3	1000	240	50	12.0	100	1	100:1	83 1/3	10
General Elec.	I-50	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
General Elec.	I-50*	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
General Elec.	I-50	16 2/3	1000	120	15	1.8	100	1	100:1	55 5/9	1
General Elec.	I-50	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
General Elec.	I-55	16 2/3	1000	240	15	3.6	100	1	100:1	27 7/9	1
General Elec.	I-50	16 2/3	1000	240	50	12.0	100	1	100:1	8 1/3	1
General Elec.	I-50	16 2/3	1000	240	50	12.0	100	1	100:1	83 1/3	10
Sangamo	J-2	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
Sangamo	J-2*	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
Sangamo	J-2	16 2/3	1000	120	15	3.0	100	1	100:1	33 1/3	1
Sangamo	J-2	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
Sangamo	J-2	16 2/3	1000	240	15	6.0	100	1	100:1	16 2/3	1
Sangamo	J-2	16 2/3	1000	240	50	12.0	100	1	100:1	8 1/3	1
Sangamo	J-2	16 2/3	1000	240	50	12.0	100	1	100:1	83 1/3	10
Westinghouse	D	16 2/3	1000	120	2.5	0.3	100	1	100:1	333 1/3	1
Westinghouse	D*	16 2/3	1000	120	5	0.6	100	1	100:1	166 2/3	1
Westinghouse	D	16 2/3	1000	120	15	1.8	100	1	100:1	55 5/9	1
Westinghouse	D	16 2/3	1000	240	2.5	0.6	100	1	100:1	166 2/3	1
Westinghouse	D	16 2/3	1000	240	15	3.6	100	1	100:1	27 7/9	1
Westinghouse	D	16 2/3	1000	240	30	7.2	100	1	100:1	13 8/9	1
Westinghouse	D	16 2/3	1000	240	30	7.2	100	1	100:1	138 8/9	10

* This rating probably not in production.

DEFINITIONS

K_h = WATTHOUR CONSTANT	Watthours per revolution of the watthour meter disk. This is often referred to as the Meter Constant or Disk Constant. Engraved as part of the meter nameplate data.
K_s = WATTSECOND CONSTANT	Wattseconds per revolution of the meter disk. Since there are 3600 seconds per hour, it is $K_h \times 3600 = K_s$.
R_r = REGISTER RATIO	The gear ratio of the first gear of the register to one revolution of the first (units) pointer on the dial. It is the complete gear ratio of the detachable register and is generally stamped in the register metal or printed on the register face.
R_g = GEAR RATIO	The gear ratio of the disk to one revolution of the first (units) pointer on the register dial. It is the complete gear ratio of the meter. In other words, it is the number of revolutions of the disk required to cause one complete revolution of the first (unit) pointer of the dial.
K_r = REGISTER CONSTANT	The number by which the dial readings must be multiplied to obtain true kilowatt-hours. This is also called the Multiplier, Dial Multiplier, and Multiplying Constant. For most self-contained meters, the register constant is one or ten. (10 is generally used on 50 ampere meters with 4 dial registers). Where the Register Constant is the result of use of current and the potential transformers, it is generally marked on the meter as M and is the product of the C.T. and P.T. ratios. It is sometimes combined with the K_h of the meter and labeled as Primary K_h and equals K_h x C.T. ratio x P.T. ratio.
REDUCTION AT SHAFT	The ratio of the number of revolutions of the disk to make one revolution of the first gear of the register. Actually, this is the ratio of the number of teeth on the first gear on the register to the number of teeth on the disk shaft. Shafts having single pitch worms are equivalent to a one-tooth gear.

EQUATIONS FOR DETERMINING WATTHOUR METER CONSTANTS

$$K_h = \frac{\text{Volts x Amperes (nameplate)}}{\text{Rev. per Hour (design)}} \quad (1)$$

$$\text{Watthours} = K_h \text{ x Number of Revolutions of Disk} \quad (2)$$

$$\text{Kilowatt-hours} = \frac{K_h \text{ x Number of Revolutions of Disk}}{1000} \quad (3)$$

$$\text{Gear Ratio, } R_g = \frac{\text{Revs. of Disk}}{\text{Revs. of 1st. Dial}} \quad (4)$$

$$\text{Gear Ratio, } R_g = \frac{10{,}000 \text{ x } K_r}{K_h} \quad (5)$$

$$\text{Register Ratio, } R_r = \frac{10{,}000 \text{ x } K_r}{K_h \text{ x Red. at Shaft}} \quad (6)$$

$$\text{Register Constant, } K_r = \frac{R_r \text{ x } K_h \text{ x Red. at Shaft}}{10{,}000} \quad (7)$$

Where Current and/or Potential Transformers are used:

$$\text{Register Constant, } K_r = \frac{R_r \text{ x } K_h \text{ x Red. at Shaft x CT x PT (ratios)}}{10{,}000} \quad (8)$$

$$\text{Kilowatts} = \frac{K_h \text{ x PT x CT x 3600 x No. of Revs.}}{\text{1000 x Seconds for Revs.}} \quad (10)$$

VALUE FOR POWER FACTOR
USING

TWO ELEMENT WATTHOUR METER ON BALANCED DELTA LOAD

S_1 = Seconds for N revolutions of Fast Element
S_2 = Seconds for N revolutions of Slow Element

Where Both Elements Run Forward

$\frac{S_1}{S_2}$	%P.F.	$\frac{S_1}{S_2}$	%P.F.	$\frac{S_1}{S_2}$	%P.F.	$\frac{S_1}{S_2}$	%P.F.	$\frac{S_1}{S_2}$	%P.F.
0.847	99	0.554	89	0.381	79	0.246	69	0.117	59
0.790	98	0.525	88	0.367	78	0.233	68	0.104	58
0.747	97	0.507	87	0.353	77	0.220	67	0.092	57
0.712	96	0.490	86	0.339	76	0.207	66	0.079	56
0.681	95	0.473	85	0.325	75	0.193	65	0.066	55
0.654	94	0.457	84	0.312	74	0.181	64	0.053	54
0.629	93	0.441	83	0.298	73	0.168	63	0.039	53
0.605	92	0.425	82	0.285	72	0.156	62	0.026	52
0.583	91	0.410	81	0.272	71	0.143	61	0.013	51
0.563	90	0.396	80	0.259	70	0.130	60	0.000	50
Where The Slow Element Runs Backward									
0.013	49	0.154	39	0.312	29	0.498	19	0.729	9
0.027	48	0.169	38	0.329	28	0.519	18	0.756	8
0.041	47	0.183	37	0.346	27	0.540	17	0.784	7
0.054	46	0.199	36	0.364	26	0.562	16	0.811	6
0.068	45	0.214	35	0.382	25	0.584	15	0.840	5
0.082	44	0.230	34	0.400	24	0.606	14	0.870	4
0.096	43	0.246	33	0.419	23	0.630	13	0.902	3
0.110	42	0.262	32	0.438	22	0.654	12	0.933	2
0.125	41	0.279	31	0.458	21	0.678	11	0.967	1
0.139	40	0.295	30	0.478	20	0.703	10	1.000	0

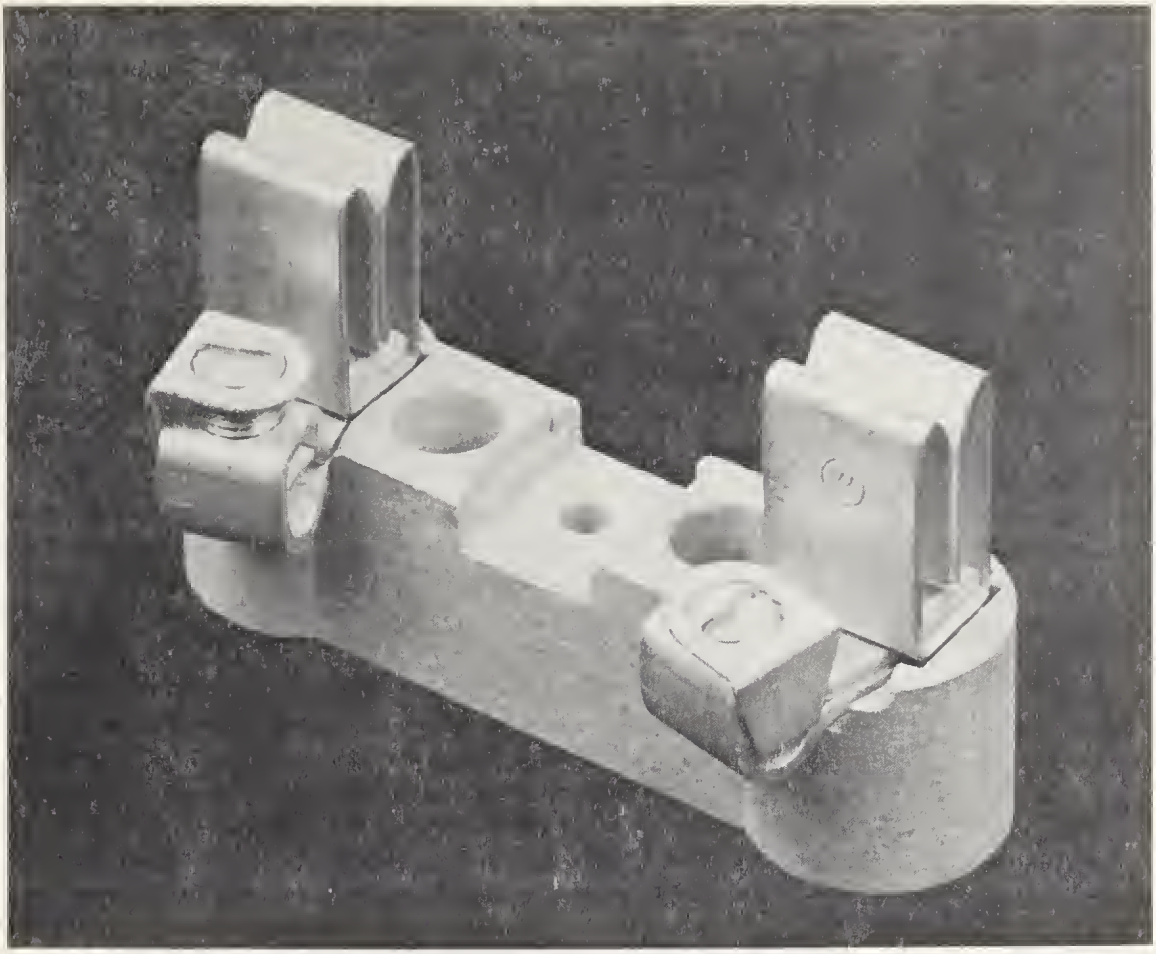


Fig. 1. Standard duty jaw assembly

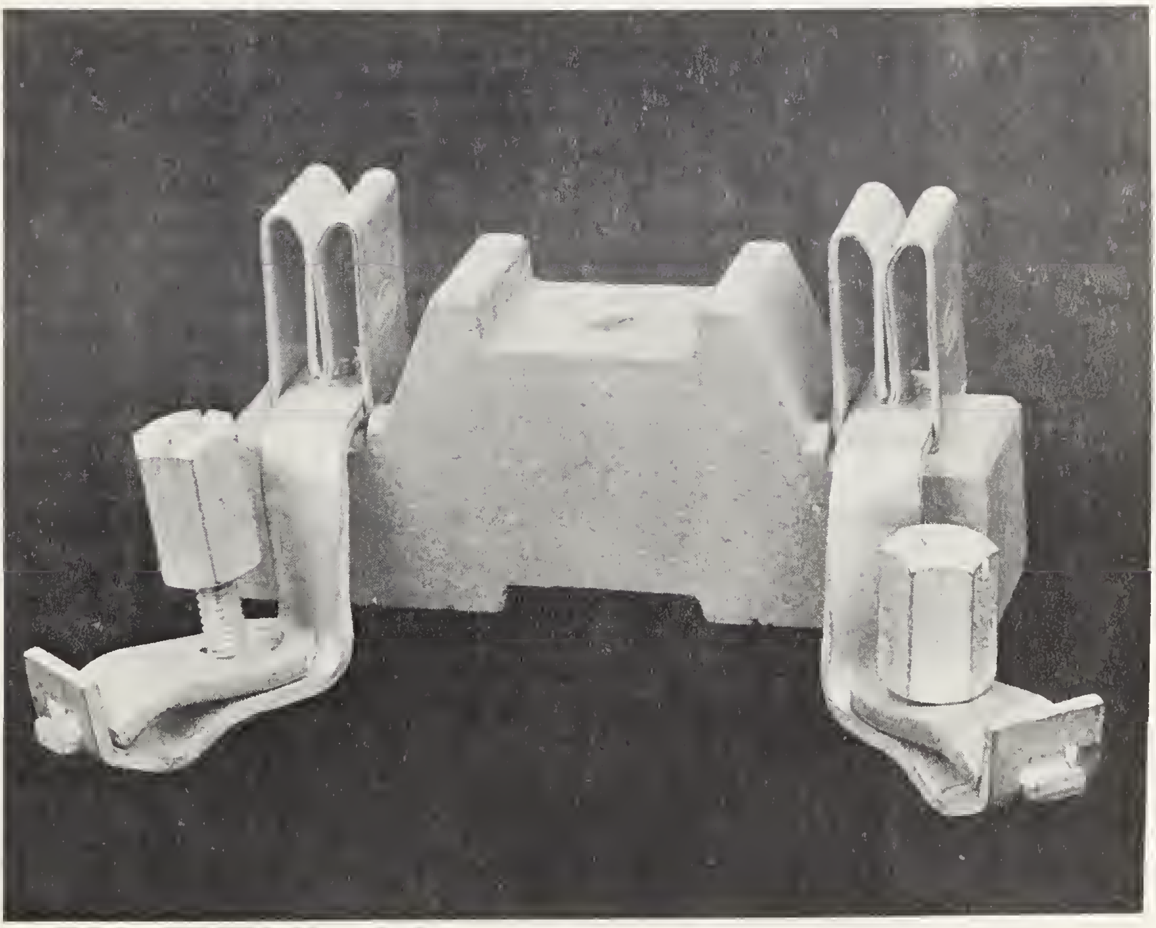


Fig. 2. Standard duty jaw with 100 ampere terminals

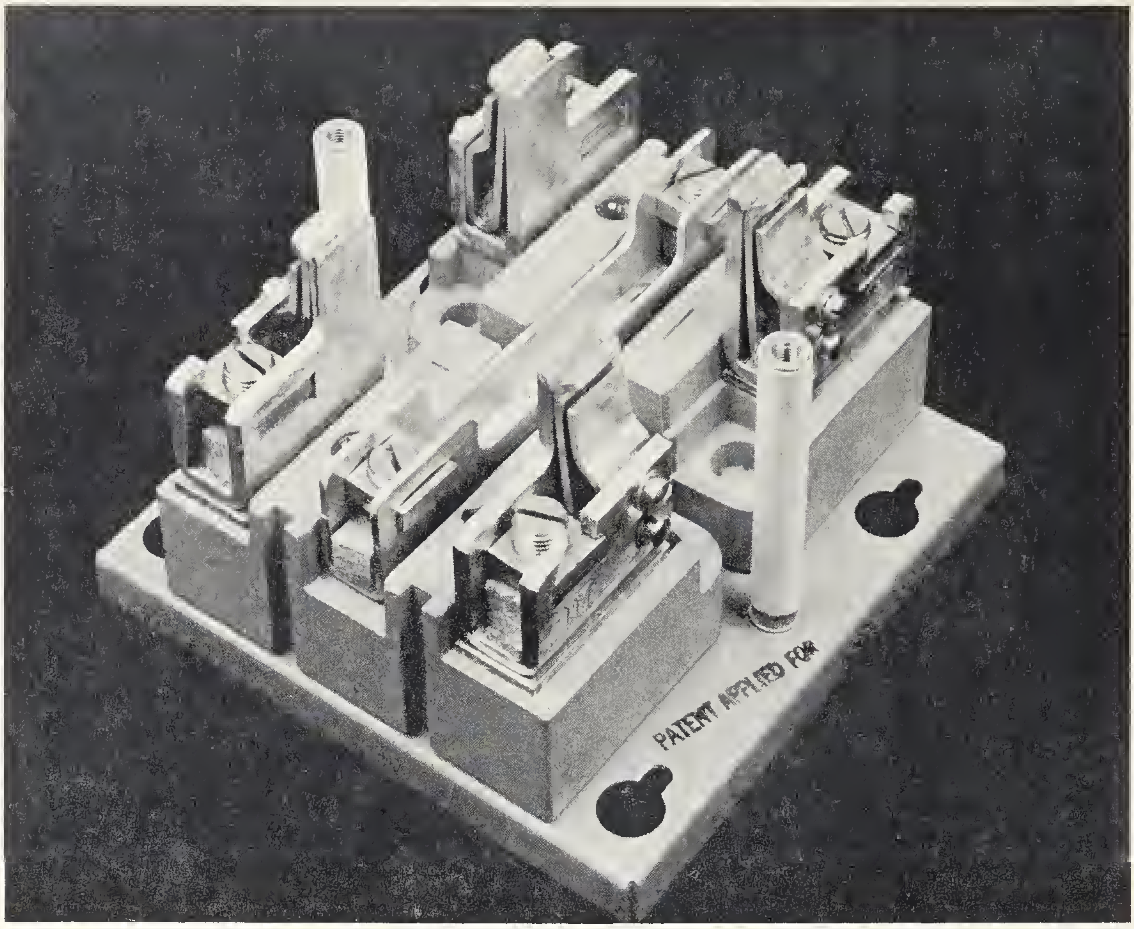


Fig. 3. Medium duty jaw assembly 150 ampere capacity

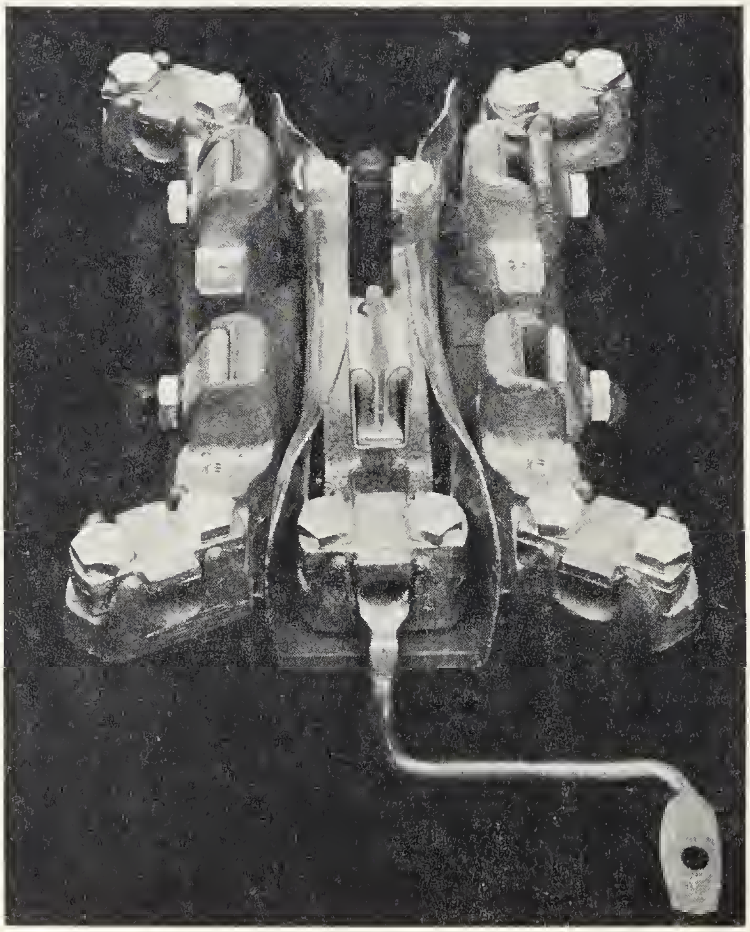
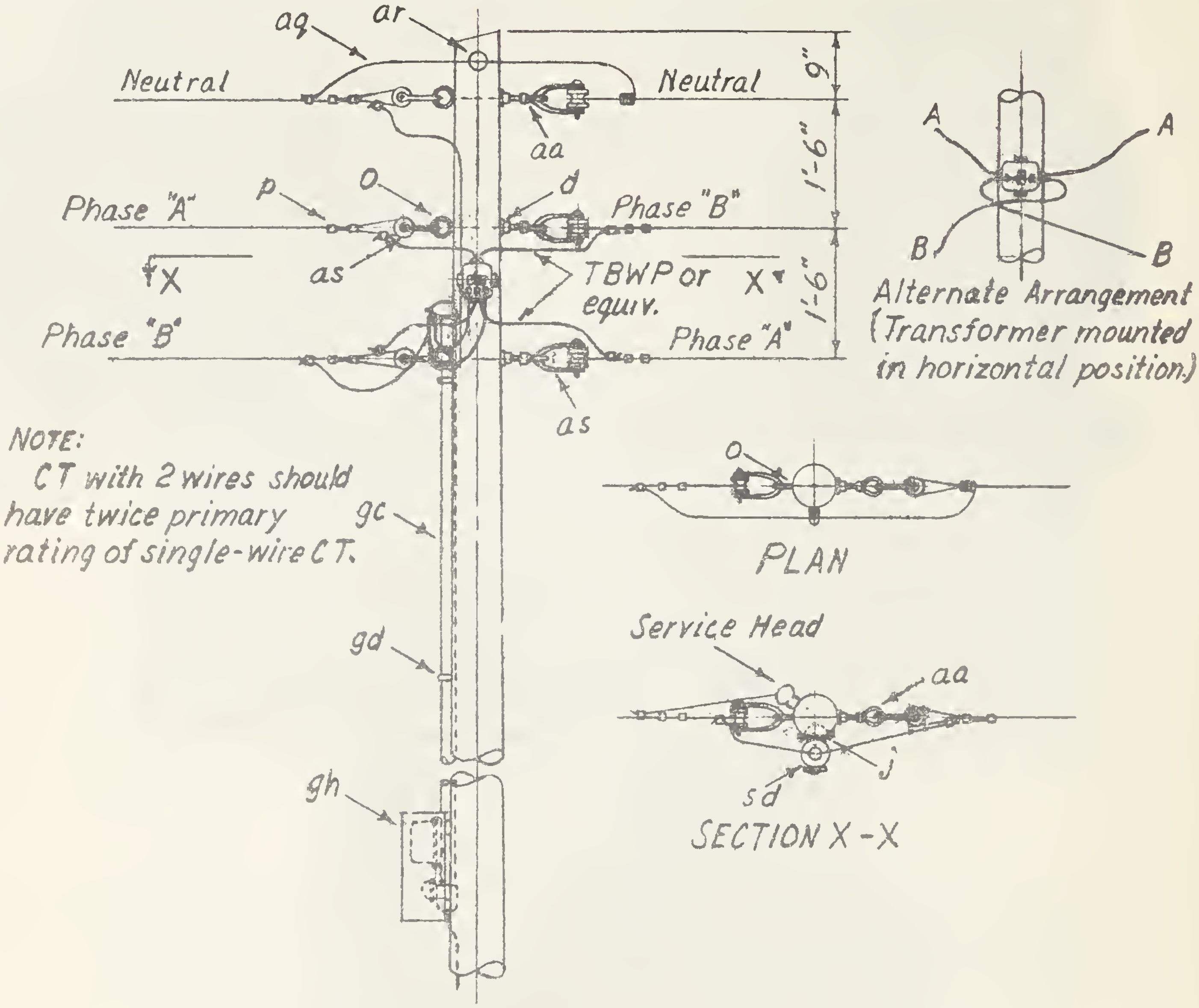


Fig. 4. Heavy duty jaw assembly 200 ampere capacity

Fig. 5. Through-type current
transformers 600 volt service



ITEM	NO. REQD.	MATERIAL		ITEM	NO. REQD.	MATERIAL	
d	3	Washer, 2¼"x2¼"x3/16", 13/16" hole		gd		Straps, conduit, as required	
j	2	Screw, lag		ge	1	Condulet, type LB	
o	3	Bolt, eye, 5/8" x reqd. length			1	Service Head	
p		Connectors, as required		gh	1	Meter box, meter and test block	
aa	3	Nut, eye, 5/8"		sd	1	Transformer, current	
aq		Jumpers, Insulated				Wire, No. 12 for current and	
ar	1	Wireholder				No. 14 for potential	
as	6	Clevis, service, swinging, insulated					
gc		Conduit, 1¼" as required					

SECONDARY METERING GUIDE

SINGLE PHASE 3-WIRE METERING 240 VOLTS

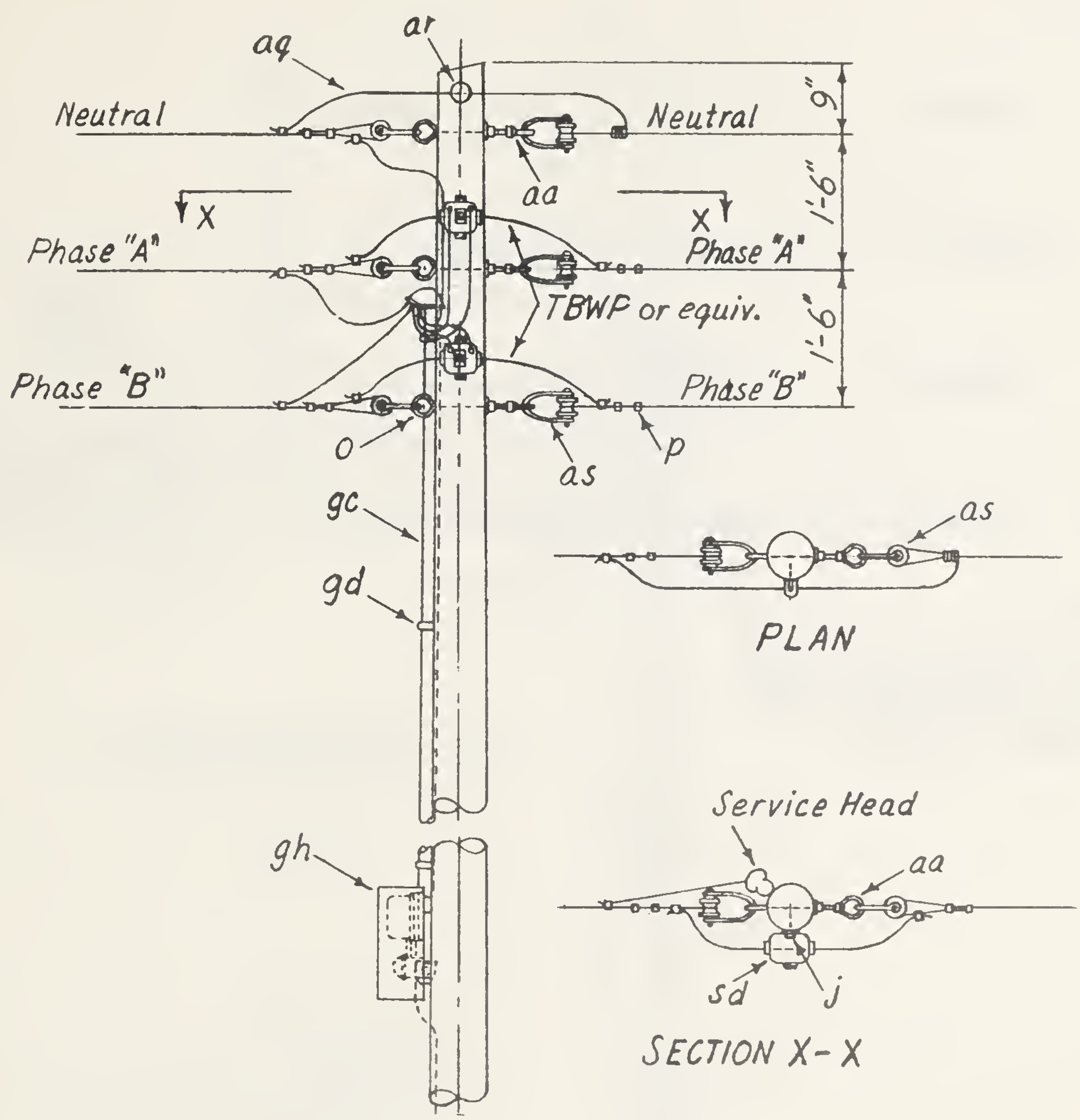
Scale: ½" = 1'-0"

Date: Sept. 15, 1954

No.	REVISION	DATE:

A-3589

MB-6

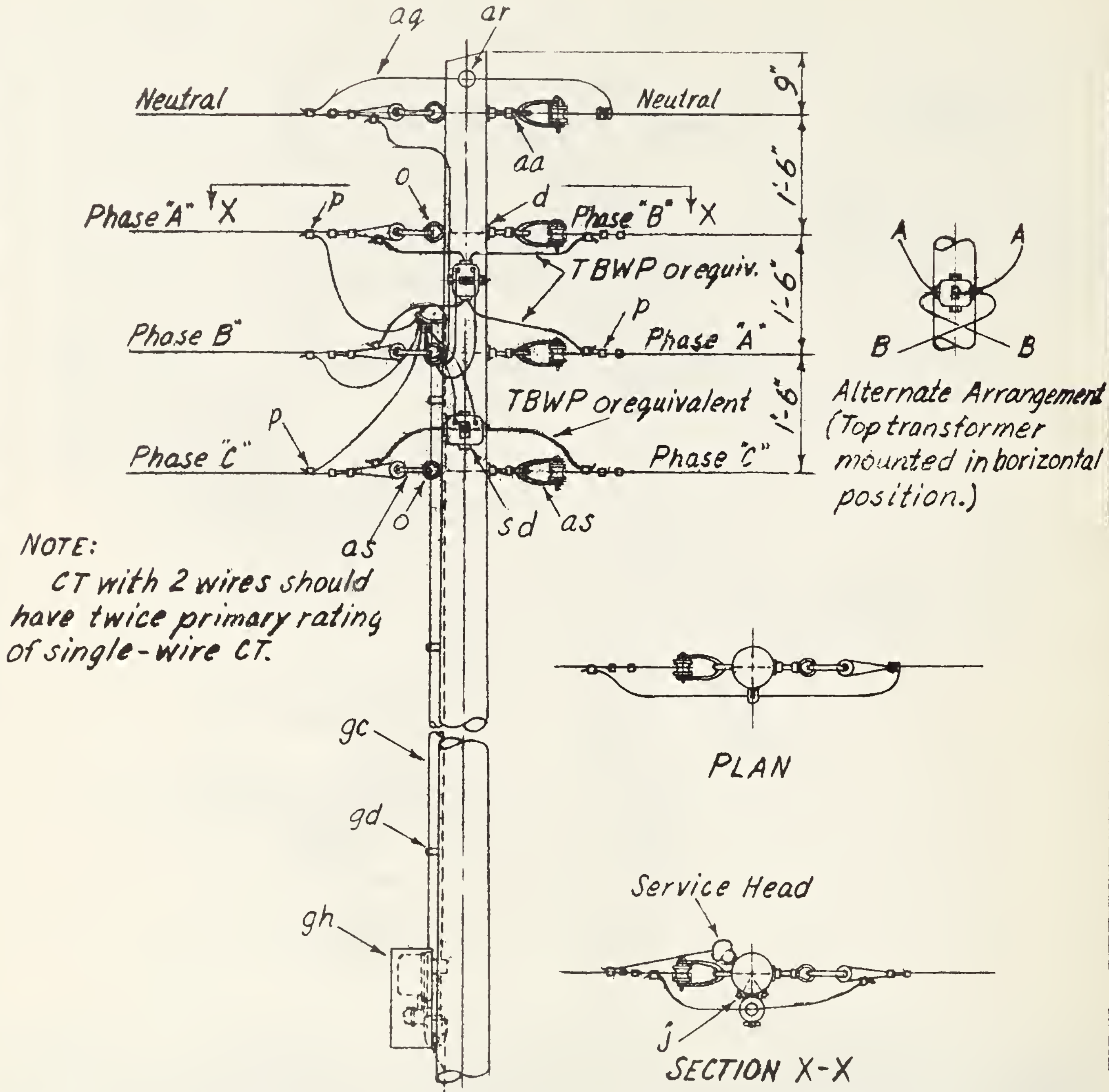


ITEM	NO. REQ'D	MATERIAL		ITEM	NO. REQ'D	MATERIAL	
d	3	Washer, 2 1/4" x 2 1/4" x 3/16", 13/16" hole		gd		Straps, conduit, as required	
j	4	Screw, lag		ge	1	Condulet, type LB	
o	3	Bolt, eye, 5/8" x req'd. length			1	Service Head	
p		Connectors, as required		gh	1	Meter box, meter and test block	
aa	3	Nut, eye, 5/8"		sd	2	Transformer, current	
aq		Jumpers, Insulated				Wire, No. 12 for current and	
ar	1	Wireholder				No. 14 for potential	
as	6	Clevis, service, swinging, insulated					
gc		Conduit, 1 1/4" as required					

SECONDARY METERING GUIDE

THREE PHASE 3-WIRE METERING 240 VOLTS

NO.	REVISION	DATE:	Scale: 1/2" = 1'-0"	Date: Sept. 16, 1954
				A-3590



Alternate Arrangement (Top transformer mounted in horizontal position.)

NOTE:
CT with 2 wires should have twice primary rating of single-wire CT.

PLAN

Service Head
j

SECTION X-X

ITEM	NO. REQ'D	MATERIAL	ITEM	NO. REQ'D	MATERIAL
d	4	Washer, 2¼"x2¼" x 3/16", 13/16" hole	as	8	Clevis, service, swinging, insulated
j	4	Screw, lag	gc		Conduit, 1¼" as required
o	4	Bolt, eye, 5/8" x req'd. length	gd		Straps, conduit, as required
p		Connectors, as req'd.	ge	1	Condulet, type "L B"
aa	4	Nut, eye, 5/8"		1	Service Head
aq		Jumpers, insulated	gh	1	Meter box, meter and test block
ar	1	Wireholder	sd	2	Transformer, Current
		Wire, No. 12 for current and			
		No. 14 for potential			

SECONDARY METERING GUIDE
THREE PHASE 4-WIRE Δ METERING 240 VOLTS

Scale: ½" = 1'-0"

Date: Sept. 15, 1954

A-3591

NO.	REVISION	DATE:

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D. C. AND A. C. CALCULATING BOARDS

By John G. Hieber

For Presentation at the Technical Training Conference
For REA Field Engineers, Chicago, Illinois
January 17 - 21, 1955.

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

D.C. AND A.C. CALCULATING BOARDS

(Also called Network Analyzer or Network Calculator)

John G. Hieber

Introduction

The first calculators were placed in operation in 1929. There are approximately 50 A.C. boards in use by colleges, manufacturers, and electric companies. The development of boards is indicated by Westinghouse's increase in the size of their first board from 12 generators and 344 circuits to a present size of 36 generators and 668 circuits. Most electrical systems are too large to fit even the larger boards without some reductions and combinations of system constants. It has become standard practice to use boards for solving operating problems, planning new additions to systems, and for studying proposed interconnections. Fig. 1 lists some data that may be obtained from a board study. Accuracy claimed for A.C. boards range from 1. to 3. per cent. Rental charges vary from $100 to $200 per day. REA cooperatives have made approximately 75 board studies, each requiring one week of study time.

D.C. AND A.C. CALCULATING BOARDS

D.C. Board

The direct current calculating board consists of a number of adjustable rheostat units which may be connected together to represent a system to be studied in miniature. A known D.C. voltage is impressed between a positive and negative bus. Readings of voltage and current can be made in any part of the system by plugging in a voltmeter and ammeter.

Since the D.C. board has only resistance devices, all circuit elements are assumed to be either a reactance, an impedance, or some intermediate value. Fig. 2 shows comparison between various impedance values. Fig. 3 shows the circuit diagram of a D.C. board.

The D.C. board provides a simple and convenient means for determining the short circuit currents in a large complex system. Where phase angles, load currents, and transient conditions are to be studied, the A.C. board is generally used.

(Details of REA's D.C. board are included in Appendix A and Fig. 30.)

A.C. Board

The A.C. board is a practical, adjustable, miniature power system whereby an actual or proposed electrical system can be set up on a small test scale to permit the study of problems. The various sections of the electrical system are represented by a suitable number of adjustable resistors, reactors, and capacitors.

Each calculator element terminates in flexible connectors that can be plugged to a series of bus receptacles to reproduce the desired system. Low loss measuring instruments are provided to permit reading scalar values of voltage, current, active power and reactive power, and vector values of voltage and current in both rectangular and polar forms.

The various elements are generally connected to represent one phase, line to neutral, of a balanced three phase system.

Shunt loads are represented by resistors and reactors or capacitors with interposing transformers as shown in Fig. 4 to permit adjusting for constant load as system voltage varies. Generators are represented by adjustable static equipment as shown in Fig. 6 whose A.C. single phase voltage is adjustable both in phase and in magnitude.

The voltage-magnitude adjustment simulates adjustment of the excitation of the generator and primarily determines the RKVA output. The phase angle adjustment corresponds to the adjustment of the governor of the prime mover. Advancing the phase increases KW output and retarding phase decreases it. Each generator must be operated so that its KVA capability (Fig. 8) is not exceeded. Fig. 7 shows the representation of a two circuit transformer with exciting current neglected. Fig. 5 shows the representation of a transmission line or cable. Fig. 31 shows a complete A.C. board in operation.

Impedance Diagram - Preparation

The well-known one-line diagram shown in Fig. 9 of the power system to be studied showing generators, reactors, transformers, transmission lines, and loads is the starting point. From the one-line there is prepared a diagram in which all the significant electrical elements of the power system are represented on a single-phase (line-to-neutral) basis by their positive sequence (balanced conditions) equivalent circuits with proper values of impedances. The values of impedance of individual apparatus are commonly given either in actual ohms or in per unit (or per cent) based on the rating of the individual apparatus. For use in the system impedance diagram these values are generally converted to per-unit values on a common base. Per-unit values equals 0.01 times per cent values. Some impedance values are tabulated in the Appendix.

KVA Base

In drafting it is necessary to select proper scales such as 1/8 inch equals 1 foot. In the same way the large electrical system's impedance data, etc. is reduced to best fit the board by the proper choice of a base KVA. An example of base calculations is shown in Fig. 10. This should permit large current scale deflections in the ammeter without subjecting any of the board units to over-currents. If the current scale is too small, current and power cannot be read accurately in lightly loaded circuits.

Example of Choice of Base

One make of board has its own base rating of 100 volts, 1.0 ampere, and 100 ohms. (100 volts on the board equals 100% power system voltage.) The board's instruction book suggests the following typical base for voltage regulation studies:

TABLE I

Maximum KVA in any Power Circuit	Base to use for adapting System Data to Board
Up to 30,000	10,000
30,000 to 60,000	20,000
60,000 to 120,000	40,000

If impedances are known in actual ohms at line voltage they may be converted to any KVA base by use of following formula:

$$\text{Per cent } Z = \frac{\text{Base KVA X ohms}}{\text{Base KV}^2 \text{ X } 10} \qquad (1)$$

Assume a simple system, as shown in Fig. 9, with one generator rated 15,000 KVA, 13.6 KV, and 120% impedance connected to a step-up transformer rated 15,000 KVA, 13.6 KV to 66 KV, and 7.5% impedance. The transmission line consists of 50 miles of 4/0 ACSR with equivalent conductor spacing of 9 feet and serves a load of 12,500 KVA at 0.8 P.F.

Since the maximum KVA in any circuit is 15,000, Table I specifies a board KVA base of 10,000.

For conversion of impedances from one KVA base to another, apply:

$$\frac{\text{\% impedance base A}}{\text{\% impedance base B}} = \frac{\text{KVA of base A}}{\text{KVA of base B}}$$

Accordingly impedance of generator on 10,000 KVA base = $120\% \times \frac{10000}{15000} = 80\%$

and impedance of transformer on 10,000 KVA base = $7.5\% \times \frac{10000}{15000} = 5\ \%$.

From manuals the transmission line impedance is .464 + J.81 ohms per mile (60 cycles, 25 C, 600 amp. per sq. in.)

By use of equation (1)

$$\text{line \% resistance} = \frac{10000 \times .464 \times 50}{66^2 \times 10} = 5.32$$

$$\text{and \% reactance} = \frac{10000 \times .81 \times 50}{66^2 \times 10} = 9.3$$

Capacity susceptance (b) equals 5.67 micromhos per mile (Where $b = 2\ \pi\ f\ C$)

$$\text{\% susceptance} = \frac{\text{b (in micromhos) x base } \overline{\text{KV}}^2}{\text{Base KVA x 10}} = \frac{5.67 \times 50 \times \overline{66}^2}{10000 \times 10} = 12.3$$

On short transmission lines it is generally assumed that one-half of the susceptance is connected to each end of the line.

Load Calculations - The following formulae apply:

$$\text{\% resistance} = \frac{\text{Base KVA x 100}}{\text{Load KW}}$$

$$\text{\% reactance} = \frac{\text{Base KVA x 100}}{\text{Load KVAR}}$$

12,500 KVA at .8 P.F. = 10,000 KW + 7500 KVAR

$$\text{\% resistance} = \frac{10000 \times 100}{10000} = 100$$

$$\text{\% reactance} = \frac{10000 \times 100}{7500} = 133.2$$

Fig. 14 shows a percent impedance diagram on 10,000 KVA base at 66 KV.

Short Circuit and Relay Studies

Short circuit information is necessary for the economical application of circuit breakers, for correct application and setting of relays, and for analyzing system disturbances.

A great deal of system data is required to apply the relays of a power system properly. In general, three-phase and single-phase to ground faults for both maximum and minimum conditions of generation will be applied to all buses having circuit breakers. For some relays, the voltage of the station buses and the current in each circuit (out to two stations removed from the fault) are determined.

Short Circuits

When three-phase circuits are balanced, the determination of the voltage and current relations is relatively simple since the three-phase fault is a balanced condition. When the voltages, currents or impedances are unbalanced, the solution becomes more complex. If by some method an unbalanced circuit can be represented by a combination of several balanced circuits, each balanced circuit can be solved independently without difficulty, and the several solutions can be combined to give the complete solution. Symmetrical components represent three such circuits called zero, positive, and negative sequence.

Fig. 15 shows the measurement of positive sequence impedance. This impedance is the same as used in normal system studies.

Fig. 16 shows the measurement of negative sequence impedance. This impedance determines phase-to-phase unbalance.

Fig. 17 shows the measurement of zero sequence impedance. This impedance is present when line to ground current flows and it determines the neutral shift.

Assumptions generally made in short circuit studies are:

1. No load on all generators, and

2. Their voltages are equal and in phase.

Three-phase Fault Study

Positive sequence diagram only is used.

$$I_1 = E/Z_1$$

Example 1: A three-phase generator, as shown in Fig. 18, rated 15,000 KVA, 13.8 KV has a transient impedance of 15%. To determine its three-phase short circuit current on calculating board, assuming 15,000 base KVA, and 13.8 KV base voltage, the base amperes = $15000 \div 13.8 \times \sqrt{3} = 627.6$ amperes.

On a per unit basis $15\%\ Z = \frac{15}{100} = .15$

I_1 short circuit $= 1. \div .15 = 6.66$ P.U. current as shown in Fig. 19.

Total three-phase short circuit current $= 6.66 \times 627.6 = 4180$ amperes symmetrical.

Line to Ground Fault Current

References 1. and 2. and many texts show the derivation of the following equation for this type of fault current:

$$I_0 = \frac{E}{Z_1 + Z_2 + Z_0}$$

To conserve elements on the calculating board, it is assumed with practical accuracy that $Z_1 = Z_2$ then

$$I_0 = \frac{E}{2Z_1 + Z_0} \qquad 2\ I_0 = \frac{2E}{2Z_1 + \frac{2Z_0}{2}} = \frac{E}{Z_1 + \frac{Z_0}{2}}$$

Example 2: Line to ground fault study:

Assuming generator in Example 1 is grounded and has a Z_0 (Zero sequence impedance) of 3 % or .03 per unit

$$2\ I_0 = 1.0 \div \left(.15 + \frac{.03}{2}\right) = 6.06 \text{ P.U. as shown in Fig. 20.}$$

$$3\ I_0 = \text{total fault current} = \frac{3}{2} \times 6.06 = 9.09 \text{ P.U. or } 9.09 \times 627.6 = 5690. \text{ amp.}$$

Procedure for Using Calculating Board

1. It is assumed that the engineer has chosen a suitable base or scale for representing the power system on the board.

2. It is assumed that the system data has been converted to this base or scale.

3. He then assigns board units to the various circuits. As an indication of polarity, one cord of each circuit unit may be colored green and the other yellow.

4. Connects the board units to represent the system.

5. Sets the resistors, reactors and capacitors.

6. Adjusts the operating conditions.

7. Takes readings and records for reproduction.

Most A.C. calculating boards are under the direction of engineers experienced in design and operating problems of electric power systems and in the manipulation of the calculator apparatus.

Limitations of System

Sometimes the desired operating conditions cannot be obtained on the board. Unless a mistake has been made in connecting or setting the board units, such failure indicates that the desired condition is one that is impossible on the actual power system. After adjusting the operating condition, one should determine whether all bus voltages are within practical limits and whether any equipment is overloaded either on the board or on the power system that it represents. If any conditions are unsat-

isfactory, consideration should be given to changing either the operating conditions or the network itself by adding new lines, transformers, generators, condensers, reactors or phase-shifting transformers.

Readings

A complete set of readings is recommended at the outset in order to check the network. Fig. 24 shows symbols used on diagrams. Voltage and phase angle of each bus and active and reactive power in each circuit are usually read and recorded, as shown in Fig. 25. Currents are read when accurate loss data is desired. The following checks may be made:- The algebraic sum of the active power of all circuits on the same bus should be zero; likewise, the algebraic sum of the reactive power. The difference of power at the two ends of a line may be taken to see whether I^2R loss is reasonable; a similar test may be made for reactive power and I^2X. Total generation equals system losses plus system loads. This is an approximate check on system losses. For large complicated systems the most valuable check is for a person familiar with the power system being studied to see whether all results appear reasonable. Fig. 26, 27, 28, 28A, and 28C show some actual system studies.

Reactive Power

The following equipment produces reactive power (leading current-positive):

1. Overexcited synchronous machines.

2. Capacitive loads and static capacitors.

3. Distributed capacitance of transmission lines.

The following consumes reactive power:

1. Underexcited synchronous machines.

2. Inductive reactive loads.

3. Induction motors.

4. Reactance of transformers.

5. Reactance of transmission lines.

In a transmission line the amount of reactive power produced is dependent on voltage (E^2/X_C) and the amount consumed on the current (I^2X_L). In general for best efficiency, corrective reactive power should be produced as near as possible to the point at which it is consumed. Operating problems such as switching often cause a compromise location.

Presentation of Results

A study of load division diagrams requires that general limits be established by which system performance may be judged. It is impossible to set definite rules for these operating limits and the final decision must be based partly on judgment. Fig. 29 shows some voltage limits proposed by an Electric Company.

In establishing the maximum allowable voltage regulation, allowance must be made for the most advantageous use of transformer taps, voltage regulators, switched re-

active Vars and generator voltage swings. For normal operation satisfactory service calls for providing 90 to 105 % of normal voltage on the supply side of the regulator at the distribution substations. Many generators are capable of swinging their bus voltage plus or minus 5 percent.

By utilizing distribution substation voltage regulators with a corrective range of plus and minus 10 percent, satisfactory service can be maintained. In systems having two transmission voltages, a plus or minus 10 percent tap changing under load transformer may be used.

Voltage limits during emergency conditions may be 5 to 10 percent lower than during normal conditions. From an examination of "duration of load curves" which are typical for REA type systems, it is noted that the peak load exists for a relatively short period of time. At 45 percent load factor, loads above 80 percent of peak load exist for only 5 percent of the time. In reviewing the merit of the various plans under emergency conditions, it is not necessarily a requirement of a plan to provide entirely adequate service at a given peak load, but that it may be considered adequate from an operating standpoint if the system will perform satisfactorily for 80 percent of the peak load.

System Stability

When two synchronous machines are coupled electrically, with one machine driving the other, there is a mechanical displacement between the rotors of the machines. The angle of this displacement is a function of the magnitudes of the internal voltages of the machines, the power transferred between the machines, and the reactance of the tie between the machines, including the internal reactance of the machines. The equation generally used to express these relationships is:

$$\text{Transferred Power} = \frac{E_1 \, E_2 \sin \phi}{X}$$

Fig. 21 shows a steady state stability curve.

Losses in the system are usually neglected. Losses introduce damping but do not affect the basic phenomena.

By definition, a stable position is one at which a small temporary displacement angle results in a restoring force which tends to restore the system to its initial condition. Steady-state stability generally refers to the system operating under relatively normal conditions where load changes are fairly gradual. Synchronous machine reactance is used. Dynamic stability occurs when a machine is operating past the steady-state stability limit. When a generator is operating at lagging power factor, the internal voltage, Ed, is larger than the terminal voltage. The steady-state pull-out limit is much larger than any possible continuous operating point. As the power factor of the machine load is increased in a leading direction the steady-state pull-out limit decreases.

Any automatic voltage regulator will allow operation in the dynamic stability region. A continuous acting regulator has advantages over the dead-band type of regulator. No regulator can act fast enough to compensate for very fast system disturbances because of the inherent time delays in the generator. However, the machine itself has extra capacity for fast changes. By the time the machine oscillation is operating on a curve of negative slope, the regulator has raised the field current. Fig. 22 shows a dynamic and transient stability curve. Transient stability and transient reactance is used when a large system disturbance occurs suddenly. This dis-

turbance may be due to a faulted line, sudden loss of a large load or loss of a heavily loaded generator. Fig. 23 shows some transient stability swing curves for Dairyland.

System stability limits can be increased by adding transmission lines or decreasing the reactance of existing lines with series capacitors. High speed relays and reclosing breakers are very useful in increasing stability limits. The proper location of connections to new generation stations is important. Ties to other systems help in general but studies must be made since a tie can cause a system to be less stable. Lowering short circuit ratio of generators has an appreciable effect. The A.C. board is generally used for making stability studies.

The details of making a stability study are explained in references 1, 3, 4, and 5.

When is a Study Required

Many power companies make one or more studies each year. Some REA power cooperatives have made approximately one study per year when their construction activity was at a maximum. Some distribution cooperatives with several generating plants have made a total of one or two studies. Small special studies may sometimes be submitted to some of the operating staffs of A.C. calculating boards for solution on a fee basis without any cooperative engineers or others being at the study. Systems with more than two generating plants generally require a board study due to circuit complexities. The time when a study should be made depends on the operating problems and plans for future construction, interconnections, etc. REA's D.C. board may be used for relaying problems, short circuit studies, etc.

REFERENCES

1. Electric Transmission and Distribution Reference Book - Westinghouse.

2. Circuit Analysis of A.C. Power Systems - Edith Clark.

3. G-E Network Analyzers Manual - GET 1235.

4. Power System Stability - E. W. Kimbark.

5. Westinghouse A.C. Network Calculator Manual.

6. Performance Charts for 60-Cycle Transmission Lines - G.E. Company, GED-560.

APPENDIX A

D.C. Board

REA's board consists of 106 circuit rheostats adjustable from zero to approximately 2.0 per unit impedance, 12 rheostats adjustable from zero to approximately 6.0 per unit. Two rheostats are suitable for representing negative impedance. Two instruments are provided,- one reads 0 to 1.2 per unit voltage; the other is a milliammeter which reads per unit impedance and per unit current. The power supply consists of two 22.5 volt Burgess batteries. Circuit rheostats may be interconnected to form the system diagram on the panel. A fault may be plugged in anywhere -- any circuit may be opened, closed, checked, or adjusted to a new valve without rearranging connections. Voltage between any two points may be read without measurably affecting current magnitudes. The minimum rheostat setting should not be less than 0.005 per unit. The maximum fault current should not exceed 10. per unit.

APPENDIX B

Surge Impedance Loading (SIL) of

Transmission Lines

The load that may be transmitted over a given line depends on many factors, such as distance to power source, characteristics of the line and load, type of station equipment and service required. Surge impedance loading provides an approximate comparative capability rating between various voltage levels of lines having suitable reactive control equipment. This loading equals approximately 2.5 times line KV^2. For such loading, line I^2X_L equals line E^2X_C.

Line KV	SIL *KW	A M P	Charging KVA Per 100 Mi.
34.5	3,000	50	600
46	5,300	66	1,000
69	12,000	100	2,500
115	33,000	166	7,000
138	48,000	200	10,000
161	65,000	233	13,000

(*Multiplying Factors: 300 mi. = 1. 200 mi. = 1.25 100 mi. = 1.6)

APPENDIX C

System Constants (Approximate)

		Time
Xd	= Direct - axis Synchronous Reactance	Continuous
X'd	= Direct - axis Transient Reactance	1/2-2. Sec.
X"d	= Direct - axis Sub-transient Reactance	0.1 Sec.
X_2	= Negative Sequence Reactance	
X_0	= Zero Sequence Reactance	

Distributed - Pole Generators (Turbine Generators)

Xd = 0.9 - 1.2
X'd = 0.17 - 0.24
X_0 = 0.03 - 0.08
X"d = 0.12 - 0.17
X_2 = 0.12 - 0.17
(All in P.U.)

Reactance of 60 cycle transformers varies from 5 % to 11 %

X (positive) = X_2 = X_0 for grounded delta-wye two winding transformers.

In transmission lines, X (positive) = X_2

X_0 = 2.5 to 3.5 times X(positive).

APPENDIX D

Transmission Line Impedance Data
(Dairyland Study)

ACSR Conductor Size	R Ohms Per Mile	Reactance - In Ohms Per Mile for Different Spacings in Feet 4.51'	5.3'	11'	16'
1/0	.893	.757	.777	.869	-
2/0	.718	.747	.766	-	-
3/0	.579	.737	.798	-	-
4/0	.464	.727	.746	.838	.880
266.8 MCM	.350	-	-	.756	.798
336.4 MCM	.278	-	-	.742	.786

Per Cent Resistance and Positive Sequence 60 Cycle Inductive Reactance on a 10,000 KVA Base

ACSR Conductor Size	34.5 KV R	34.5 KV X 4.51'	34.5 KV X 5.3'	69 KV R	69 KV X	138 KV R	138 KV X
1/0	.75	.637	.654	.188	.183	-	-
2/0	.604	.629	.645	-	-	-	-
3/0	.486	.620	.671	-	-	-	-
4/0	.39	.612	.628	.0975	.176	.0244	.0463
266.8 MCM	-	-	-	.0736	.159	.0184	.0420
336.4 MCM	-	-	-	.0585	.156	.0146	.0414

APPENDIX E

60 Cycle Capacity Susceptance "b" to Neutral in Micromhos Per Mile of Each Conductor

ACSR Conductor Size	4 Feet	11 Feet	15 Feet
1/0	6.15	5.19	4.95
2/0	6.28	5.28	5.04
3/0	6.42	5.38	5.13
4/0	6.56	5.48	5.22
266.8 MCM	6.71	5.59	5.31
336.4 MCM	6.90	5.73	5.43

Line Charging VA = b x $(\text{Volts})^2$

For 4/0 ACSR at 69,000 volts, 11 feet spacing charging KVA for one mile of three-phase line equals:

$$\frac{\overline{69000}^2 \times 5.48 \times 10^{-6}}{1000} = 26.$$

APPENDIX F

Comparison of Impedance Values of Transmission Line With Transformers at 69 KV on Line Side

Transformer Size KVA	% R	% X	Impedance Angle Degrees	Ohms on Own Base KVA R	X
750	.92	7.	82.5	58.4	444.
1000	.83	7.	83.1	39.5	333.
1500	.74	7.	83.9	23.5	222.
3000	.66	7.	84.5	10.5	111.
5000	.56	7.	85.4	5.33	66.6
10,000	.47	7.	86.1	2.24	33.3

The impedance of 4/0 ACSR conductor equals .464 ohms resistance plus .838 ohms reactance at angle of 61. degrees per mile of 69 KV transmission line. The above tabulation shows that in many sections of a system the impedance drop in transformers may be larger than the line drop. Auto-transformers having less impedance than two winding transformers will cause less voltage drop.

APPENDIX G

Base Quantities

Base KV	Base KVA 100,000	Base KVA 10,000	
33	91,830	9183	Base Micromhos
66	22,960	2296	Base Micromhos
110	8264	826.5	Base Micromhos
33	1750	175	Base Amperes
66	874.8	87.48	Base Amperes
110	524.9	52.49	Base Amperes
33	10.89	108.9	Base Ohms
66	43.56	435.6	Base Ohms
110	121	1210	Base Ohms

$$\text{Base Amperes} = \frac{\text{Base KVA}}{\sqrt{3}\ \text{base KV}}$$

$$\text{Base Ohms} = \frac{(\text{Base KV})^2 \times 10^3}{\text{Base KVA}}$$

$$\text{Base Micromhos} = \frac{\text{Base KVA} \times 10^3}{(\text{Base KV})^2}$$

The above base voltages are line to line and the base KVA is three phase values. Base impedance in ohms may be defined as that impedance which will have a voltage drop across it of 100% of base voltage (L-N) when 100% current flows through it.

LOAD DIVISION PROBLEMS

1. CIRCUIT LOADINGS
2. BUS VOLTAGES
3. REACTIVE-POWER CAPACITY NEEDED
4 EFFECT OF NEW LINES AND EQUIPMENT
5. EFFECT OF INCREASED SYSTEM LOADING.
6. EFFECT OF LINE AND EQUIPMENT OUT-AGES
7. SYSTEM LOSSES

SHORT CIRCUIT PROBLEMS

1 MAXIMUM AND MINIMUM THREE PHASE AND UNBALANCED FAULTS
2 EFFECT OF VARIOUS TYPES OF SYSTEM GROUNDING

STABILITY PROBLEMS

SPECIAL CIRCUIT PROBLEMS

Fig. 1. Data obtainable from analyzer

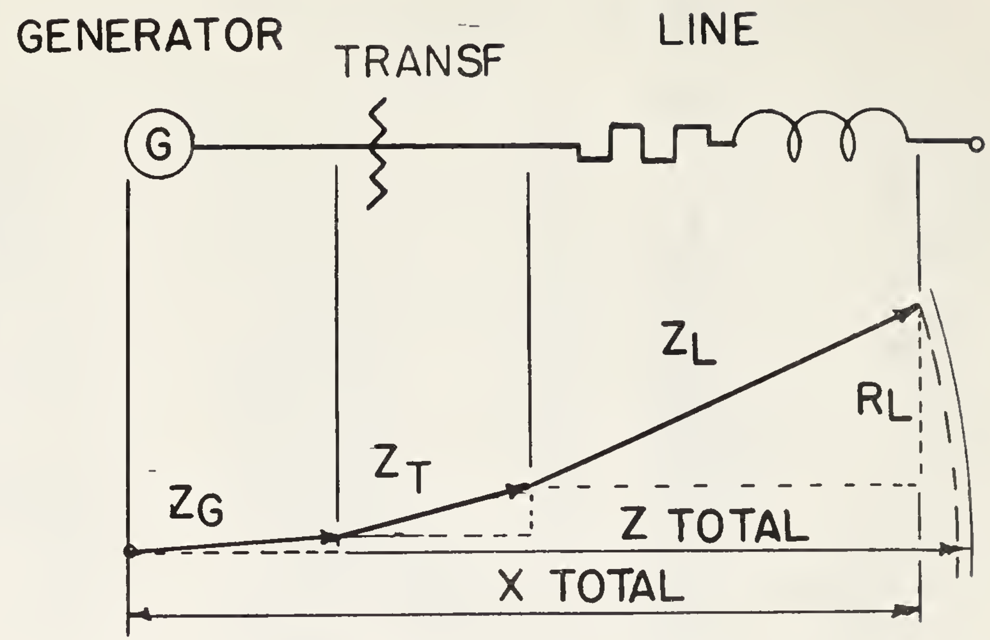


Fig. 2. Impedance diagram

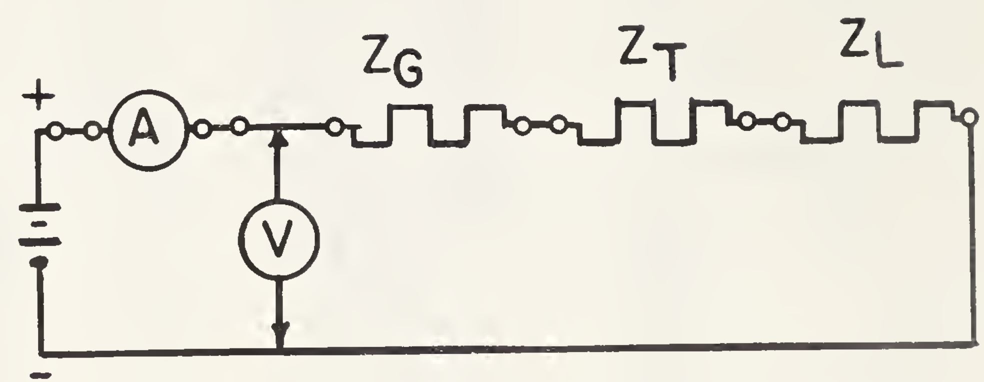
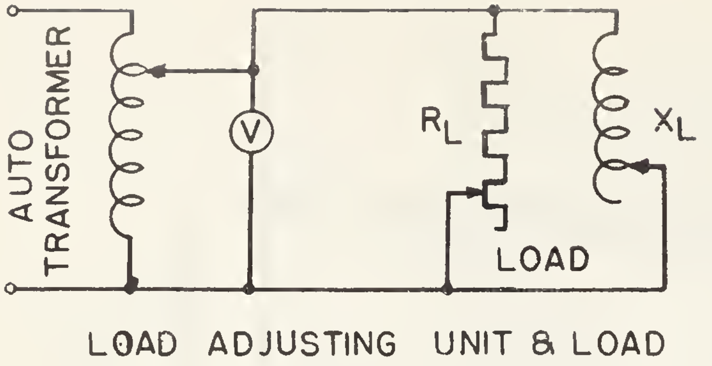


Fig. 3. D.C. board schematic diagram



$$\text{PER CENT R OR X} = \frac{\text{BASE KVA} \times 100}{\text{LOAD KW OR KVAR}}$$

Fig. 4. Schematic diagram of load adjusting unit and load

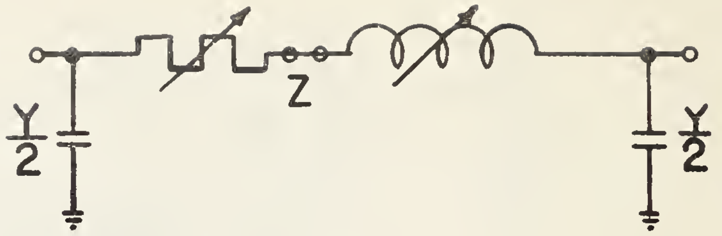


Fig. 5. Circuit representing transmission line and cable

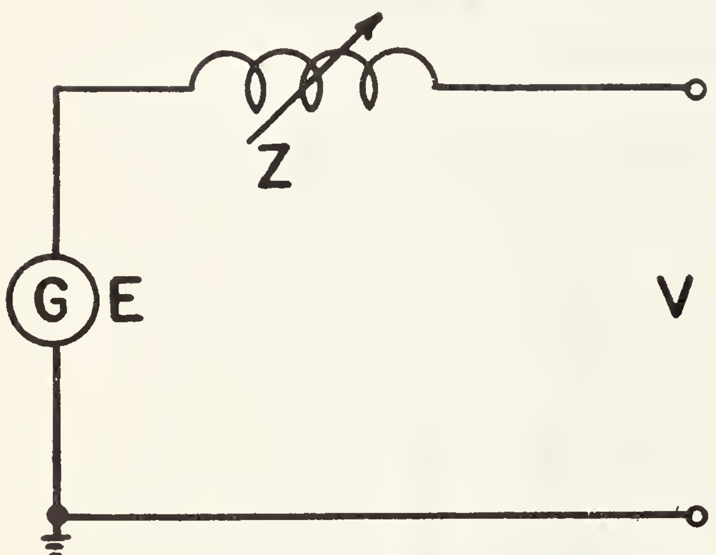


Fig. 6. Circuit representing a generator

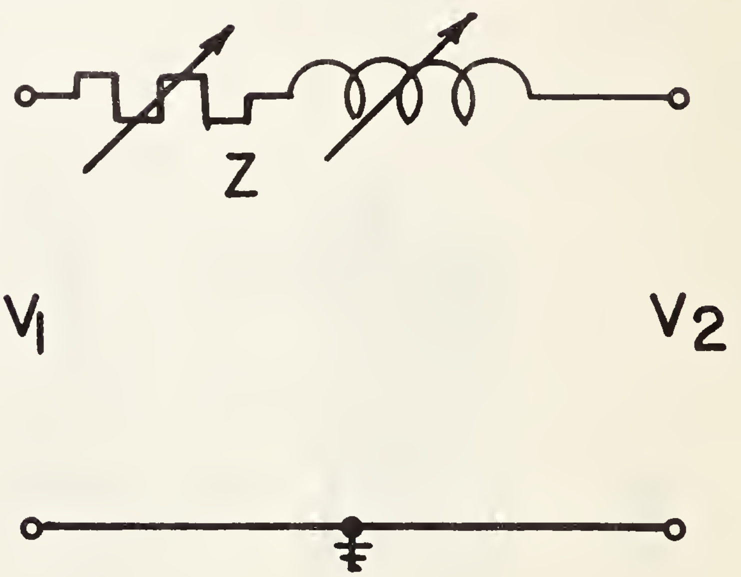


Fig. 7. Representation of a two circuit transformer

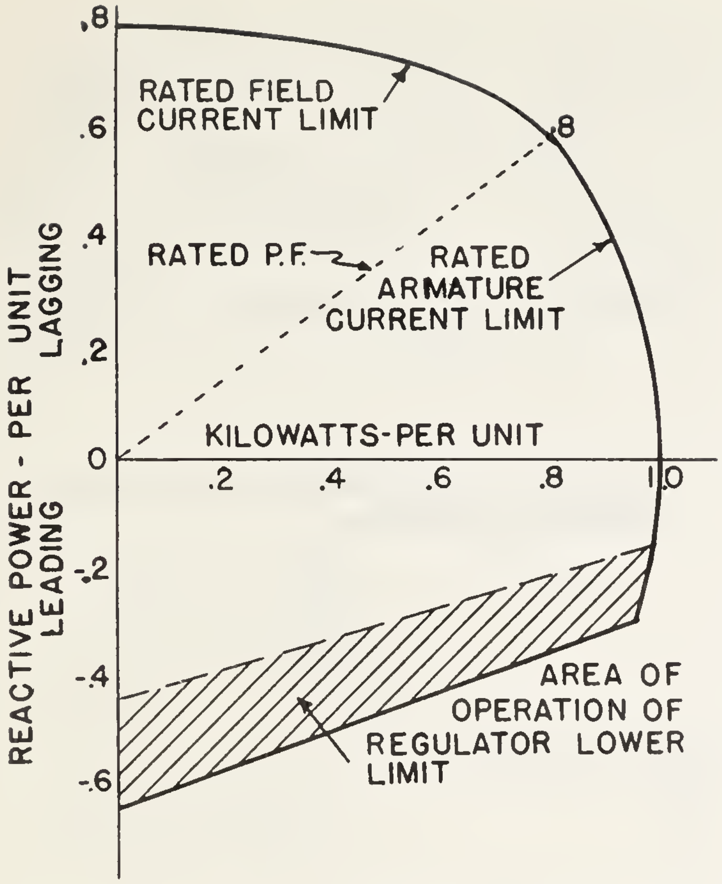


Fig. 8. Generator capability diagram

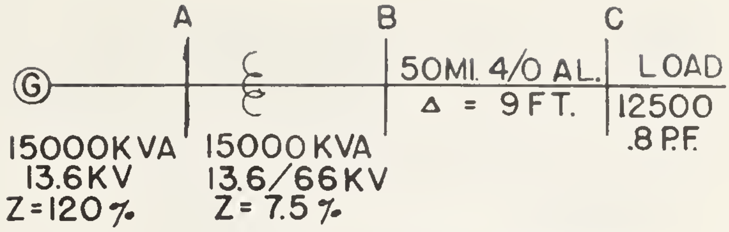


Fig. 9. One line system diagram

LET BASE KVA = 10000

LET BASE KV = 66

$$\text{THEN BASE AMPERES} = \frac{\text{BASE KVA}}{\sqrt{3}\ \text{BASE KV}} =$$

$$\frac{10000}{66 \times \sqrt{3}} = 87.48$$

$$\text{BASE OHMS} = \frac{(\text{BASE KV})^2 \times 10^3}{\text{BASE KVA}} =$$

$$\frac{66^2 \times 10^3}{10000} = 435.6$$

$$\text{BASE MICROMHOS} = \frac{\text{BASE KVA} \times 10^3}{(\text{BASE KV})^2} =$$

$$\frac{10\,000 \times 10^3}{66 \times 66} = 2296$$

Fig. 10. Base quantity calculations

PER CENT LINE REACTANCE =

$$\frac{10\,000 \times .81 \times 50}{66 \times 66 \times 10} = 9.3$$

Fig. 11. Percent line reactance calculation

PER CENT LINE SUSCEPTANCE =

$$\frac{5.67 \times 50 \times 66 \times 66}{10000 \times 10} = 12.3$$

Fig. 12. Percent line susceptance calculation

PER CENT LOAD RESISTANCE =

$$\frac{10000 \times 100}{10000} = 100$$

Fig. 13. Percent load resistance calculation

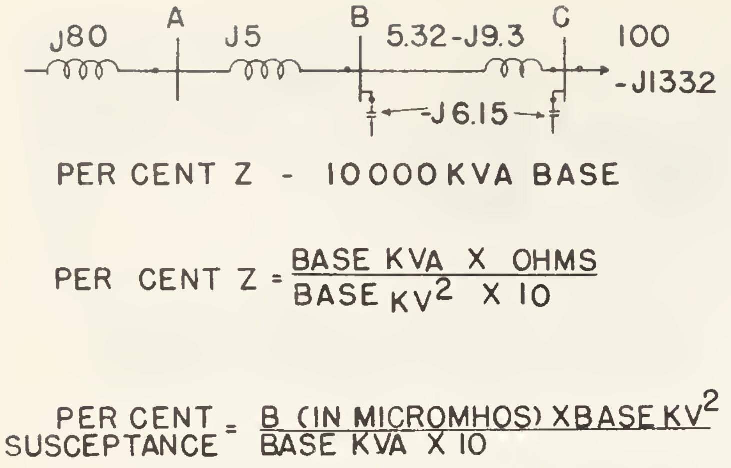


Fig. 14. Percent impedance diagram on 10,000 KVA base at 66 KV

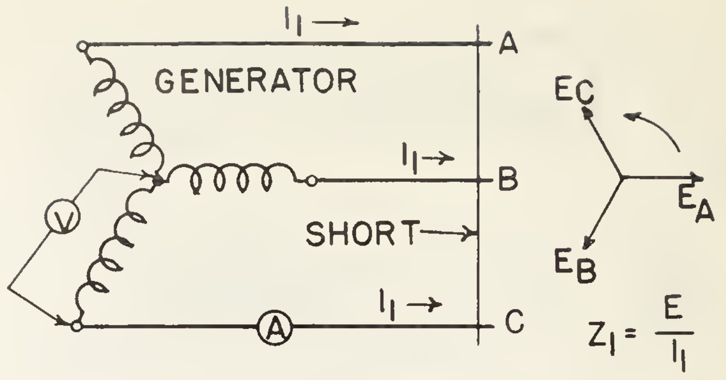


Fig. 15. Measurement of positive sequence impedance

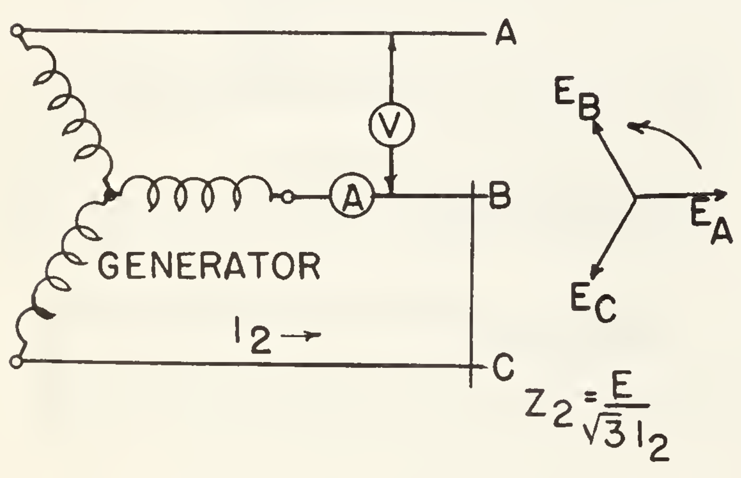


Fig. 16. Measurement of negative sequence impedance

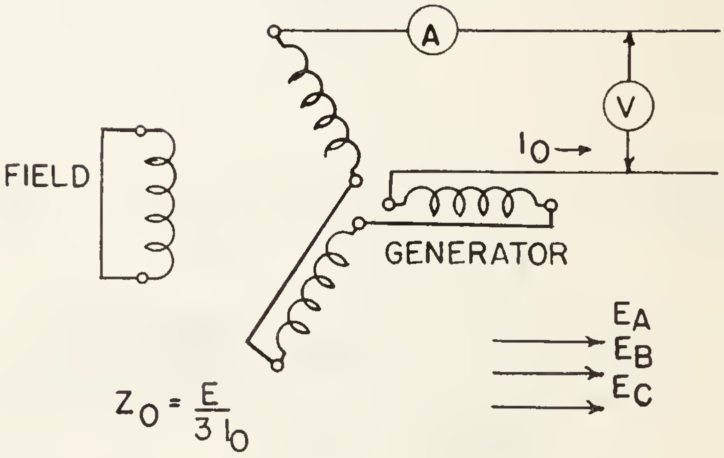


Fig. 17. Measurement of zero sequence impedance

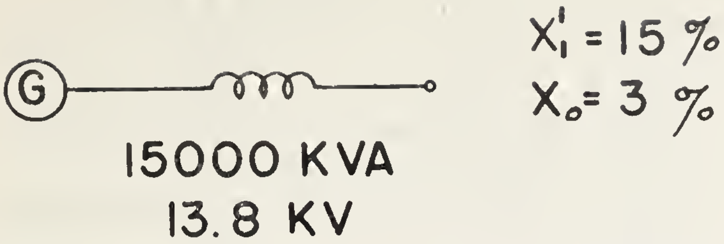


Fig. 18. Generator one line diagram

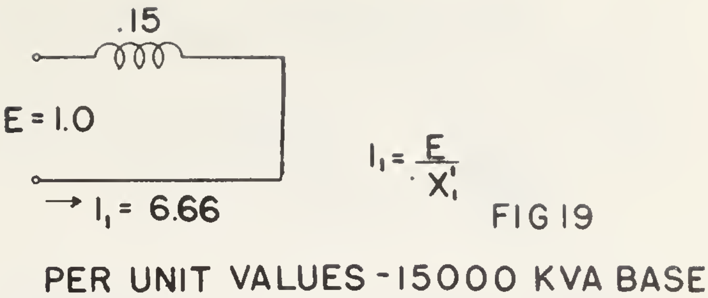


Fig. 19. Three phase fault diagram

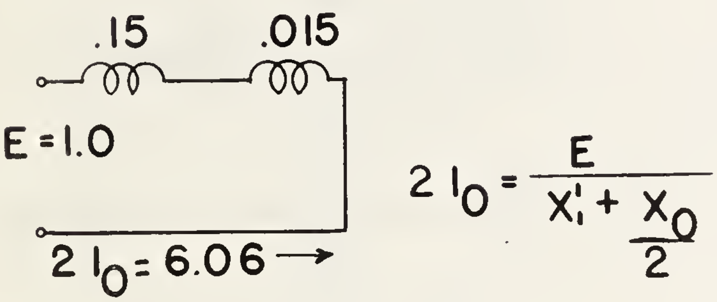


Fig. 20. Line to ground fault diagram

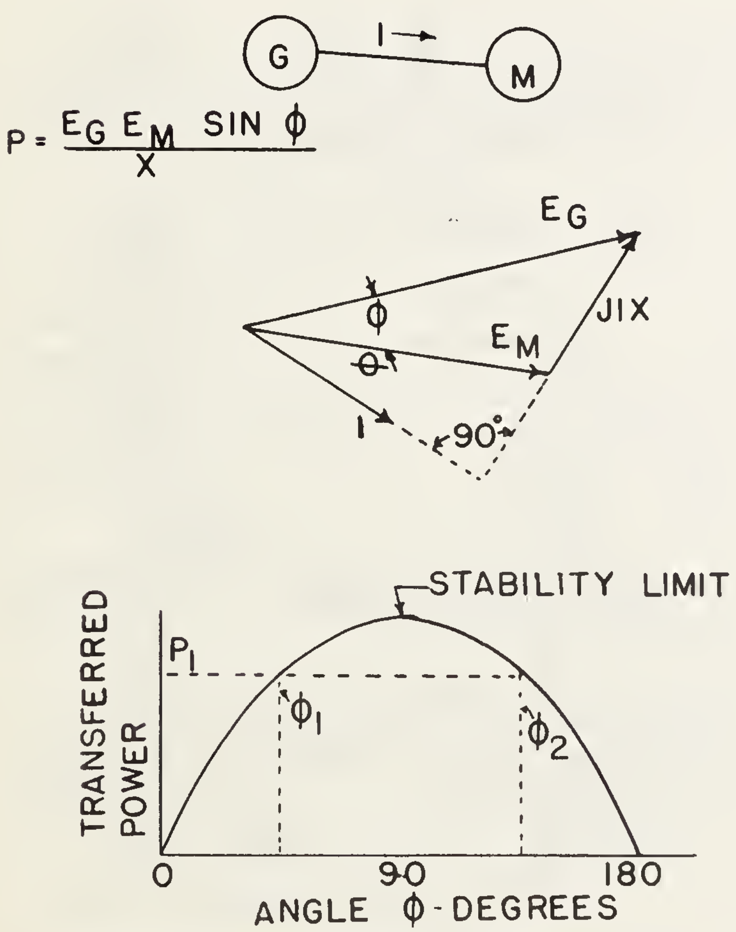


Fig. 21. Steady state stability

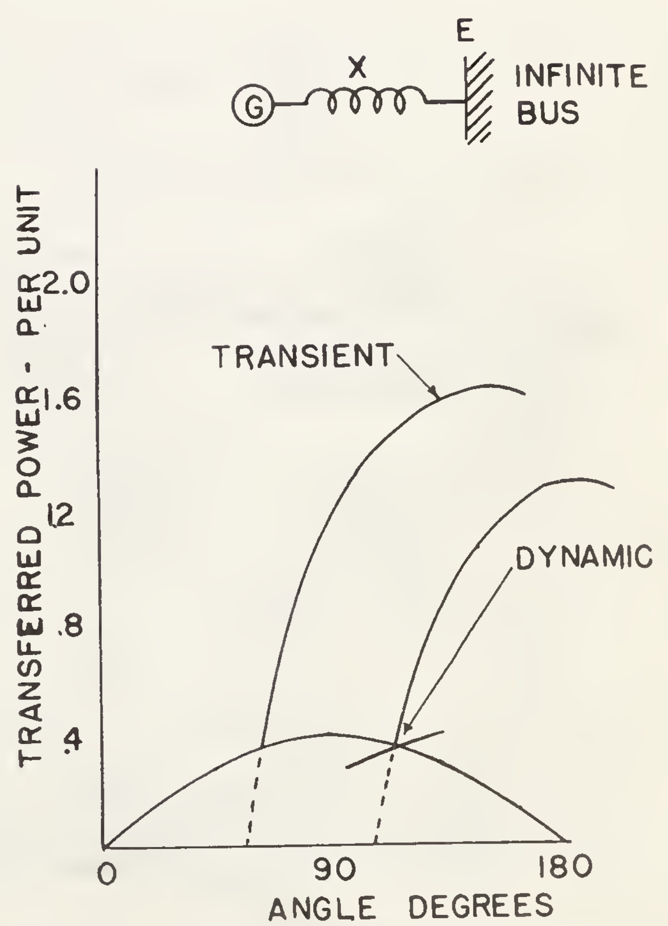


Fig. 22. Dynamic and transient stability representation curves

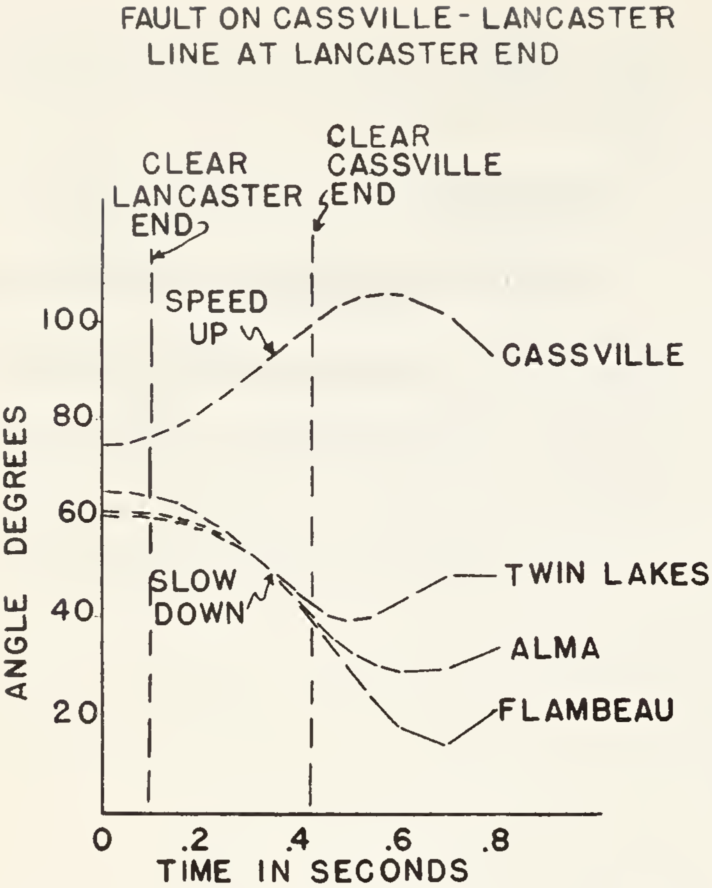


Fig. 23. Transient stability swing curves - Dairyland Power Cooperative

99 $\underline{/30°}$	PER CENT VOLTAGE & ANGLE
30 ⟶	MEGAWATTS & DIRECTION OF FLOW
(9) ⟶	MEGAVARS " " " "
↓5	TRANSFORMER TAP SETTING & DIRECTION OF BOOST
1.0 PU—	PER UNIT CURRENT & DIRECTION
Ⓖ	GENERATOR
⟼	BUS & LOAD
⊣⊢	LINE CHARGING CAPACITY
+JX	LAGGING REACTANCE
-JX	LEADING "
	LAGGING POWER FACTOR IS INDICATED WHEN WATTS AND VARS FLOW IN SAME DIRECTION

Fig. 24. Symbols used on diagrams

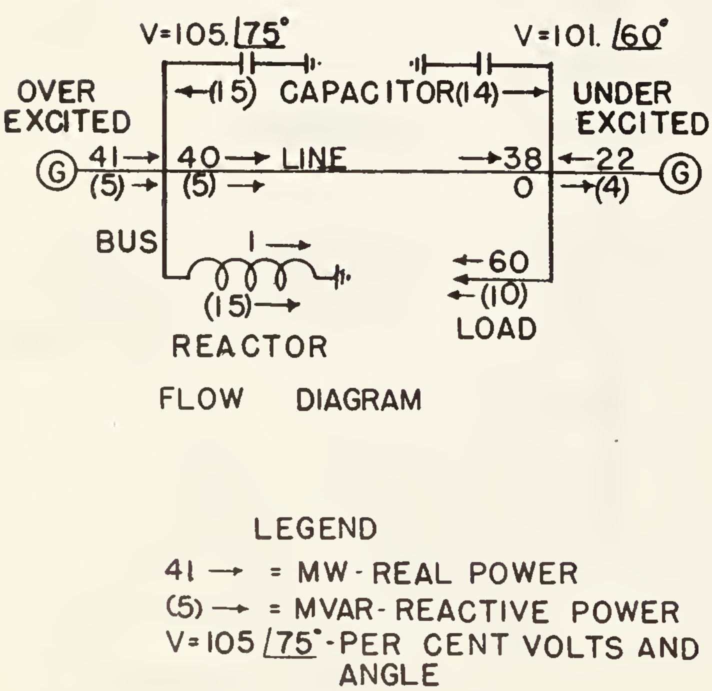


Fig. 25. Flow diagram recording

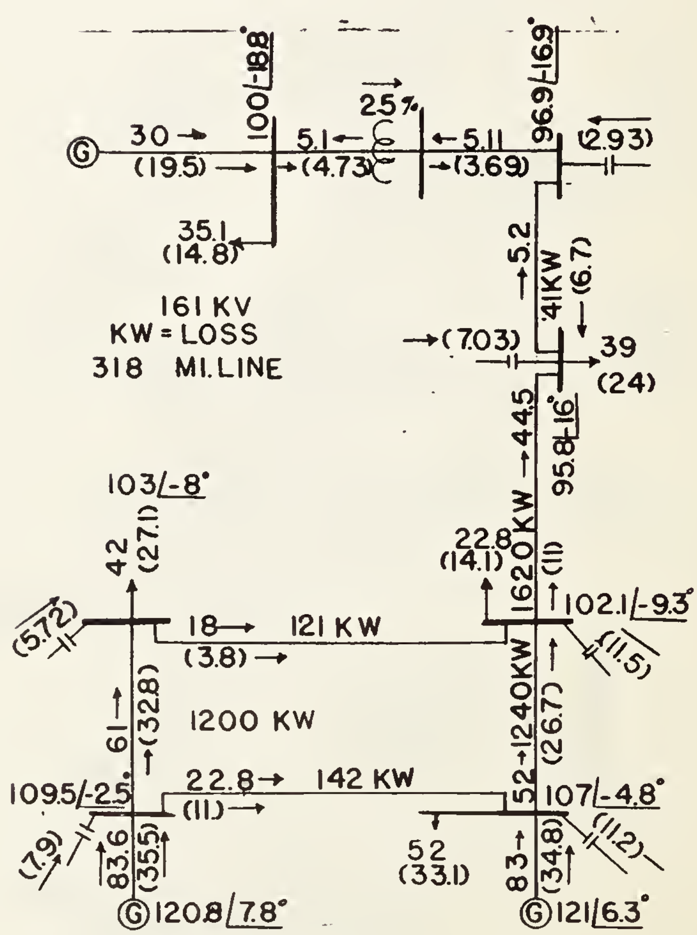


Fig. 26. 161 KV system study in Missouri

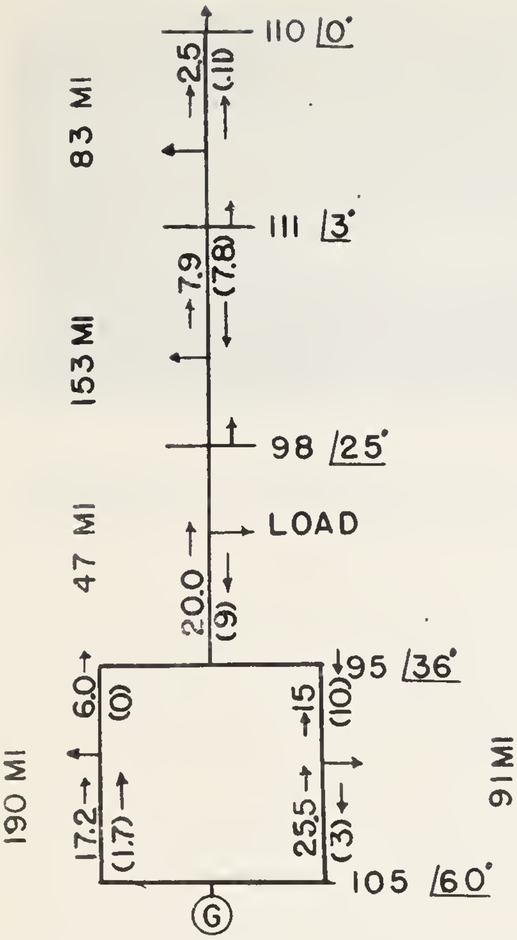


Fig. 27. 69/115 KV system study under emergency conditions

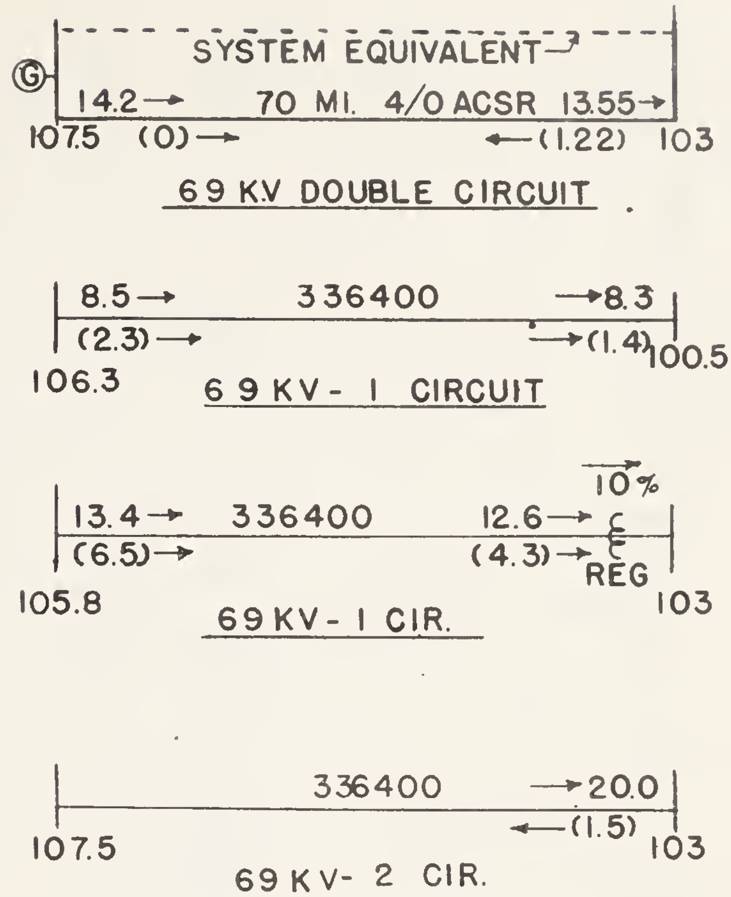


Fig. 28. Selection of conductor and voltage study - Dairyland

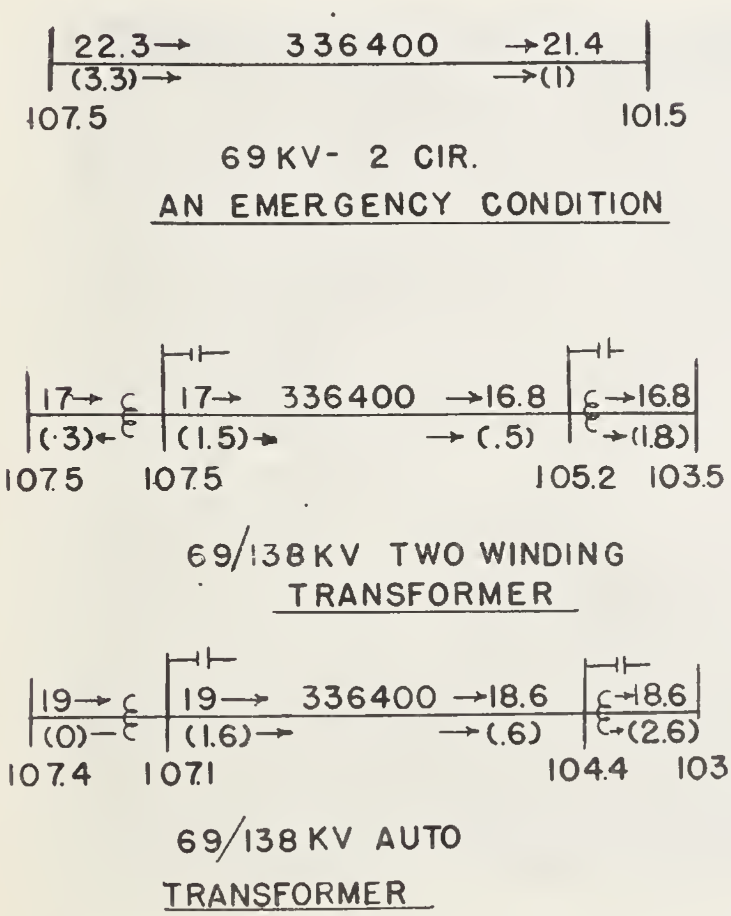


Fig. 28A. Selection of conductor and voltage study - Dairyland

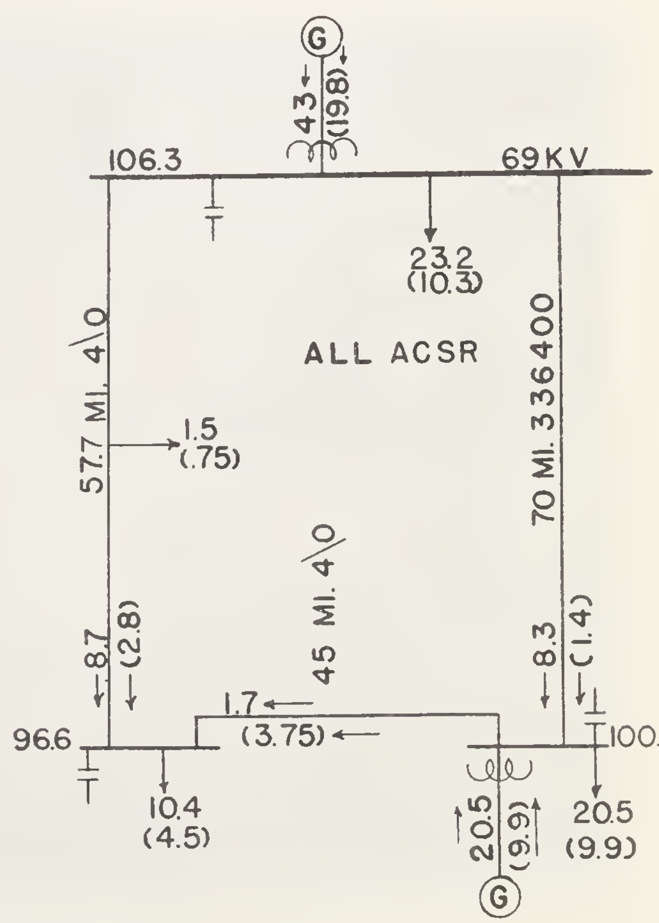


Fig. 28C. Loop system study - Dairyland

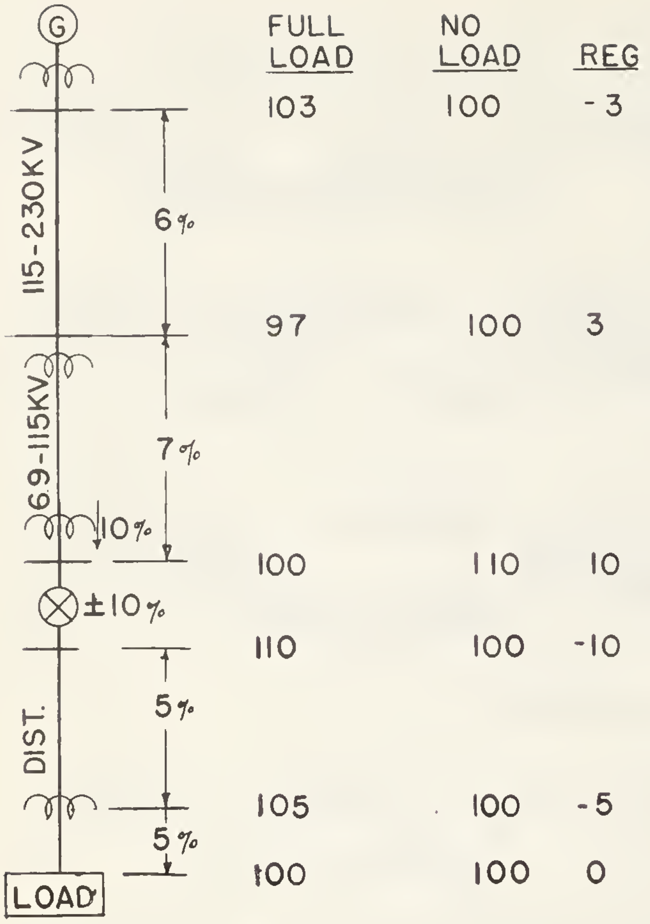


Fig. 29. Voltage level - Electric Company

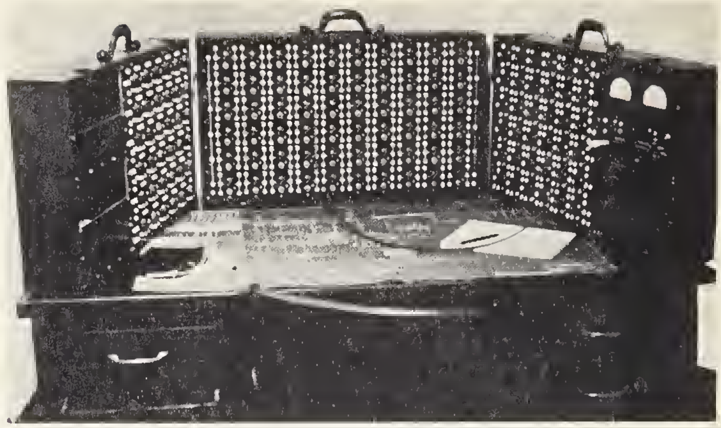


Fig. 30. D.C. board, REA, Washington, D.C.

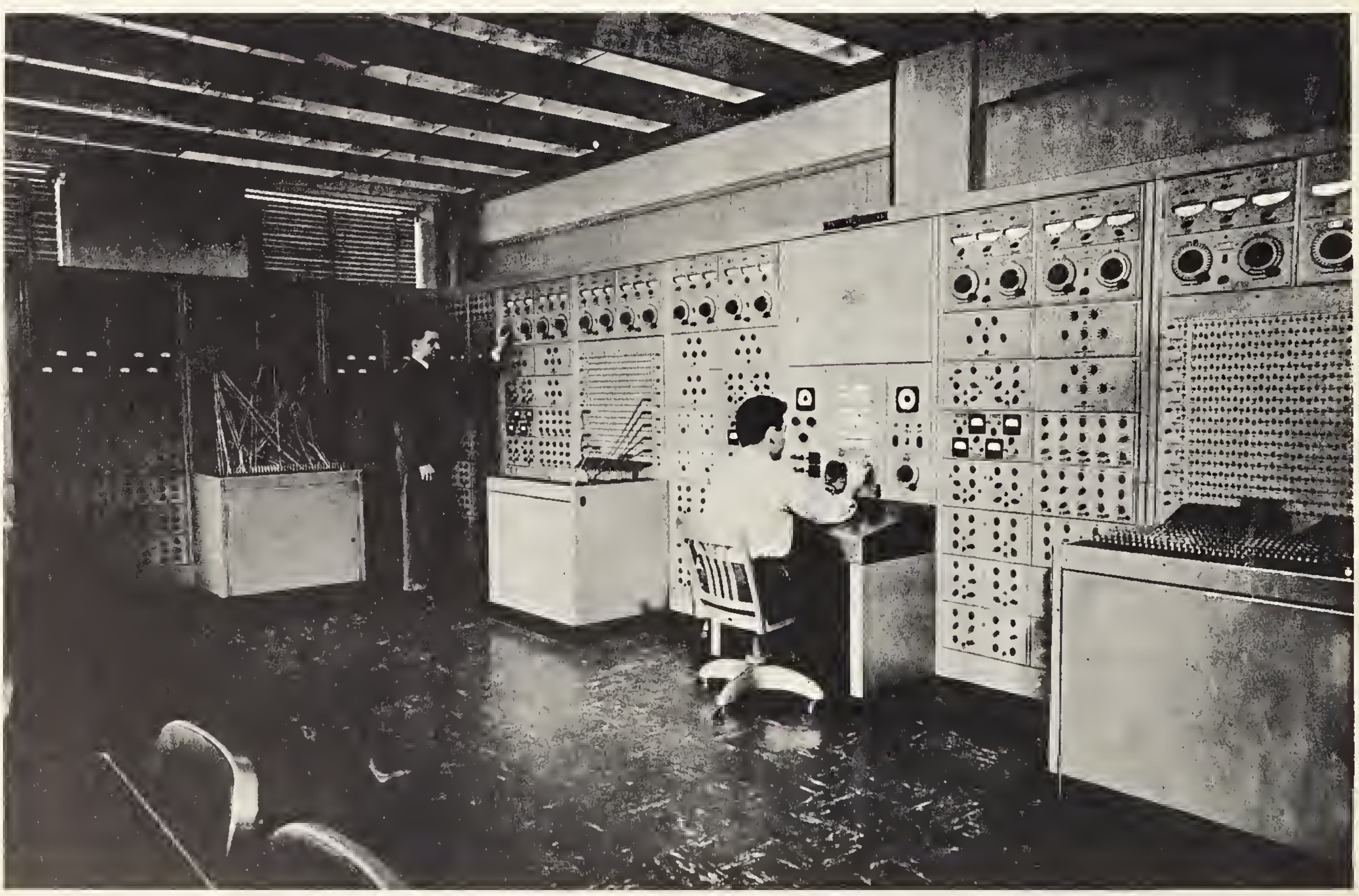


Fig. 31. A.C. board, G.E. Company, Schenectady, N.Y.

Revised

This paper in its present form does not necessarily represent official REA policy or procedures

HEADQUARTERS BUILDINGS

Design - Construction - Maintenance

By H. F. Mabbitt
Electric Engineering Division

For Presentation at the Technical Conference
For REA Field Engineers, Chicago, Illinois
January 17-21, 1955

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

HEADQUARTERS BUILDINGS

Design, Construction and Maintenance

H. F. Mabbitt

INTRODUCTION

It has been said that a building is no better than its foundation, but it should not be implied from this axiom that a good foundation will always result in a good, functional headquarters building; there are a lot of problems that need be solved before pouring the foundation. For a building to be functional, it must be designed to meet certain requirements. These requirements are not the same for each borrower; consequently a study of each case will be necessary. In addition to the specific requirements of the borrower, outside influences on the design of the structure may also be exerted by climatic conditions, local laws or building codes, topographic characteristics of the site, and the kind of building materials available locally or in preferential use in the community. The main factors, taken from these requirements and conditions, which have the greatest influence on the design of the project will be briefly elaborated upon. However, each factor, large or small, along with any particular problem of a borrower, should be given due consideration in the design and construction of the project.

SITE CONSIDERATION

Usually the first problem to be encountered, the general location, will have been solved, but for many borrowers, a big problem exists here. It may be that the electric system has grown or is growing in a direction which will no longer place the present quarters near the center of the system. The result is that operating and maintenance costs have or will become higher than they would be at a more advantageous location. Or perhaps the system has grown in several directions, or local conditions are changing and becoming such as to warrant consideration of obtaining branch facilities at one or more locations. The borrower should analyze the situation and determine whether it would be more practical and economical to operate from one central point, which might involve a relocation of present quarters, or to operate from two or more points.

If, after careful planning, it develops that branch facilities are justified, the justification will usually determine just what type of facilities will be required at each location. The next step will be to roughly estimate the size of the piece of property necessary to provide for the type of facilities desired and to include space for a pole yard and off street parking when required. It is not so important to give a lot of consideration to the size of the site except in those areas where desirable property is available only in small parcels of less than one acre and the cost is unusually high, or a great deal of site preparation will be necessary. A small or irregularly shaped site may influence the size or shape of the building and generally should be avoided. A site one acre in size will seldom be too small, and it will usually provide sufficient space for everything required including landscaping opportunities, but exclusive of a pole storage yard or transformer and conductor storage platform. Where a borrower has a choice of sites, the advantages of each location should be considered. Staffing problems, operating economies, advantages of in-town and out-of-town sites, cost of retaining, future development of the area, and future expansion of the electric system are just a few of the things that should be considered in selecting the most desirable location.

PRELIMINARY PLANS

At this point, it will be assumed that the site or sites have been selected and a general idea has been formed of just what type of facilities will be required at each location. For the purpose of illustration, it will also be assumed that branch facilities have been justified, and that the main and branch facilities will be new. It is not required however that a borrower obtain its main and branch facilities at the same time, but consideration must be given to the space requirements for the facilities to be at each location.

The next step is to plan the buildings. REA has prepared a number of Suggested Layouts of main and branch headquarters buildings to assist a borrower in the preparation of a plan for its own facilities. These layouts are available to borrowers and architects upon request. If one of these layouts is reasonably close in size and shape to the borrower's requirements, it may be used as the "preliminary plan." If none of the layouts will reasonably represent the structure as the borrower desires it, or as might otherwise be required, then the services of an architect should be obtained. This would be desirable in any event so that site development work can be illustrated, and a brief outline of specifications prepared; all of which will be needed to prepare an accurate cost estimate for the project.

A little more information about the development of the Suggested Layouts available from REA might be added here. Over a period of time, REA has been able to accumulate sufficient information to estimate the size of a building required by a borrower of a given size. When the ultimate number of miles of line to be served by a borrower can be determined, the space required for storage of vehicles and line materials can be estimated within a reasonable degree of accuracy for a typical cooperative. With the number of members known which will ultimately be served, the office space requirements can likewise be estimated. An REA bulletin will be prepared which will contain a table or graph showing REA findings on space requirements. The bulletin will explain how to use the table in the design of main and branch facilities.

Usually it will be less expensive in the long run to erect adequate facilities at the start to take care of ultimate occupancy requirements, but this is not required. Where only a portion of the ultimate requirements is proposed initially, the structure should be designed so that an addition could be erected that would not result in costly remodeling work.

ARCHITECTURAL SERVICES

A large number of borrowers are headquartered in small communities where very few or no buildings have been erected with full or even part time architectural service. Because of this, some borrowers hesitate to engage the services of an architect since they cannot understand why one would be needed. The buildings which have been erected in the community are usually store buildings. Their only requirements were four walls, a roof, floor, a few partitions, and a heating system. Quite often these buildings are of non-fire resistant construction and adjoin other buildings in which are stored inflammable materials.

The cost of these structures probably averaged about $10,000 each with few costing over $15,000. A complete headquarters project for the average size REA borrower will usually cost from four to ten times this amount. For such an investment, the best architectural service available should be obtained. A good architect

will perform many services for his clients; he will save more on construction costs than his services will cost and the appearance of the structure will certainly be more pleasing as the result of a professional touch. Moreover, it is desirable that REA retain a complete and accurate set of plans and specifications of a project for which loan funds have been used; this will usually require the services of an architect. The cost for architectural service is usually fixed at a percentage of the cost of construction, and it is not dependent upon how well qualified the architect and his staff may be. If the architect selected has already performed services for an REA borrower, his services may be more valuable than one who has not had the opportunity to become familiar with the needs of a rural electric system. Any architect should be able to develop a preliminary set of plans in a short time with a minimum amount of information and the assistance available from one of REA's suggested layouts. The accurateness of the final plans and specifications will depend considerably upon the competence of the architect and his staff or associates, and it is important that the borrower understand the necessity for retaining the best available service.

GENERAL LAYOUT

In reviewing a preliminary plan, it is well to consider good points which have been observed in other borrowers' headquarters buildings. An arrangement of rooms and offices which expedite the flow of work is that characteristic which makes the office portion functional. As for the service portion of the structure, ease in the handling and storage of materials and vehicles is the important feature. A few characteristics of a well-planned, conventional headquarters building will be given. These characteristics would also apply to a branch building where the requirements of the two structures are similar.

Generally the design will provide for a building one story in height, with emphasis on simplicity and void of expensive ornamentation. Its shape will be the result of a functional layout and each office or work area will receive natural light and ventilation even though the structure may be air conditioned. All of this may be accomplished with a minimum of waste space in corridors as is evidenced by the REA Suggested Layouts. One such layout is shown in Figure 1.

Upon entering the lobby, anyone should be greeted by the receptionist or cashier. From the lobby, it should be easy to enter, perhaps through a short corridor, all offices or areas where the person might have business. Direct entrance to every area is, of course, impossible and not desirable, particularly insofar as the manager and bookkeeper's office is concerned. The receptionist, or cashier acting as a receptionist, should to a certain extent, regulate or schedule visitors to the offices. This control need be no more than would be provided by a low gate separating the lobby and office.

Other areas accessible from the lobby would be the electrification adviser's office, directors' room (when not a part of the manager's office), demonstration area, electric appliance display and, through a short corridor, the office manager's office.

The general office, when large enough to accommodate three or more persons, should not be combined with any other office or area. Adjoining it will be the bookkeeper or office manager's office, vault, and a combination machine and office supply storage room.

CONSTRUCTION MATERIALS

As previously mentioned, the materials for construction of the building should be those locally available; such use should reduce construction costs, and identify the structure with the community. This statement usually leads to such questions as: should wood be used freely; are concrete blocks suitable for outside walls; and what about prefabricated structures. Such questions cannot be answered in this paper. A borrower should erect a structure that would last the lifetime of the loan, and it should decide for itself the kind of materials to be used. In selecting the material, the assistance of the architect should be obtained and consideration should be given to the following questions:

1. Is the material as fire resistant as we want it?

2. Are there hydrants or public fire fighting apparatus available?

3. What will the cost of insurance be on the contents of the structure as well as on the structure itself?

4. What will the maintenance costs be?

5. Can the structure be readily altered in the future, if necessary?

6. How will it compare in quality to other buildings already in the neighborhood?

7. How pleasing may it be to the eye, and will it attract other desirable business enterprises to the area?

PURCHASED AND REMODELED BUILDINGS

After a borrower decides to obtain better headquarters facilities than it already has, its first action, quite naturally, is to determine if an existing building is available which could be acquired and remodeled or expanded into adequate quarters at a cost more reasonable than it would be to erect a new building. Occasionally such quarters can be found, but ordinarily they are limited in one way or another to the type and size of quarters usually required for branch facilities. Observations reveal that seldom can an existing building be made as functional as a new one, and the cost of remodeling is almost certain to be fifty to one hundred percent greater than originally anticipated. This exemplifies the need for serious thought being given to a remodeling proposal. Just because a building can be purchased at a low initial cost per cubic foot, it does not follow that the least expensive solution to a headquarters building problem is to purchase and remodel. It is always wise to compare the estimated cost of purchasing and remodeling to the estimated cost of erecting a new building. Even though this comparison, strictly from an original cost standpoint, is decidedly in favor of purchasing and remodeling, the added convenience of the new structure should not be overlooked; the cost of insurance should also be compared, and the probable resale or actual value of each, when complete, should be considered.

PREFABRICATED BUILDINGS

In this category there are two general types of structures - wood and metal. The latter is the more popular, and it may be had in aluminum or steel or a

combination of each. Either of these metals can be obtained in a variety of shapes and sizes or pieces or units or assemblies which may be fabricated into a structure of most any size or shape. Many borrowers have found a prefabricated building to be the most economical solution to its warehousing problems or for temporary quarters; however very few borrowers have felt that such a building would be satisfactory to house its permanent office facilities. Undoubtedly more prefabricated buildings would be in general use if the cost of insurance were more favorable in some areas.

There are instances where prefabricated structures have been combined with masonry structures with a quite pleasing result from an appearance, original cost or maintenance standpoint. For temporary occupancy, where existing facilities are not available, and when it would be desirable to salvage the materials in the structure, there is little doubt as to the economy afforded by a prefabricated structure.

CONSTRUCTION PERIOD

During construction, there is very little assistance that can be given by a field representative except to look over the project during a scheduled visit to determine that workmanship is good and the materials are of the best quality, or to find places where the borrower or architect may have overlooked something significant in the design of the project. The electrical system is a place where improvements can almost always be made, but the important thing to accomplish during construction is to provide a basic electric system from which the borrower can obtain light or power in any quantity that might reasonably be required in that part of the structure.

When scheduled to visit the borrower, the field representative may, if requested, assist in closing out construction of the project. This assistance would consist of a check of the final documents and the accompaniment of the architect, contractor, and the board of directors or whoever may represent the borrower, in making the final inspection tour. Of these two things, the first would be the most important; it could expedite processing of the documents. As to the final inspection tour, this is little more than a formality since the real inspections and some tests will already have been made on the electric work, plumbing, heating and air conditioning system and other installations which are covered from view. Additional tests and adjustments will be carried on over the first year.

All material and workmanship in a headquarters building is guaranteed by the contractor for a period of one year after acceptance of the project. Borrowers should make a thorough inspection a short time before the guarantee period expires. An inspection at this time would probably reveal evidence of faulty workmanship or inferior quality materials had they been used.

MAINTENANCE

Because of the many kinds of materials, finishes and equipment used in the construction of a conventional headquarters building, no effort will be made to present information on the proper care required for each, and it is quite improbable that a borrower would expect such information from a field representative. However, there are two things that are used continuously that will require periodic care, these are the floor covering and the roof. There may be two or three kinds of floor coverings in any one building, but the kind in greatest use

is asphalt tile. Rubber and plastic asbestos tiles are also used in great quantities and each should be cleaned and waxed strictly in accordance with the manufacturer's directions if the best service is expected from them.

Even though a roof may carry a manufacturer's warrenty for a specific period, it does not mean that the roof is guaranteed not to leak for that period without a minimum amount of maintenance. A borrower should read the warranty and, if necessary, confer with the roof installer to determine just what maintenance would be required in that particular area to keep the bond in effect. Roof flashings are not always covered by the roof bond and failure to properly maintain the flashings can render the roof bond void.

There is another area where damage can be done unintentionally, that is the improper application of paint on acoustic tile or plaster. Some tiles may be painted with an oil paint without doing serious damage to their acoustic properties. Water thinned paints are best on other tiles and a number of tiles have a permanent factory finish and require cleaning only. Spray painting with a water thinned paint is considered desirable in either case where the tile or plaster is to be painted.

For the more expensive or complicated equipment, the manufacturer will furnish a book of instructions on the use and care of the equipment. This book should be available at all times to the person responsible for the proper functioning of that piece of equipment.

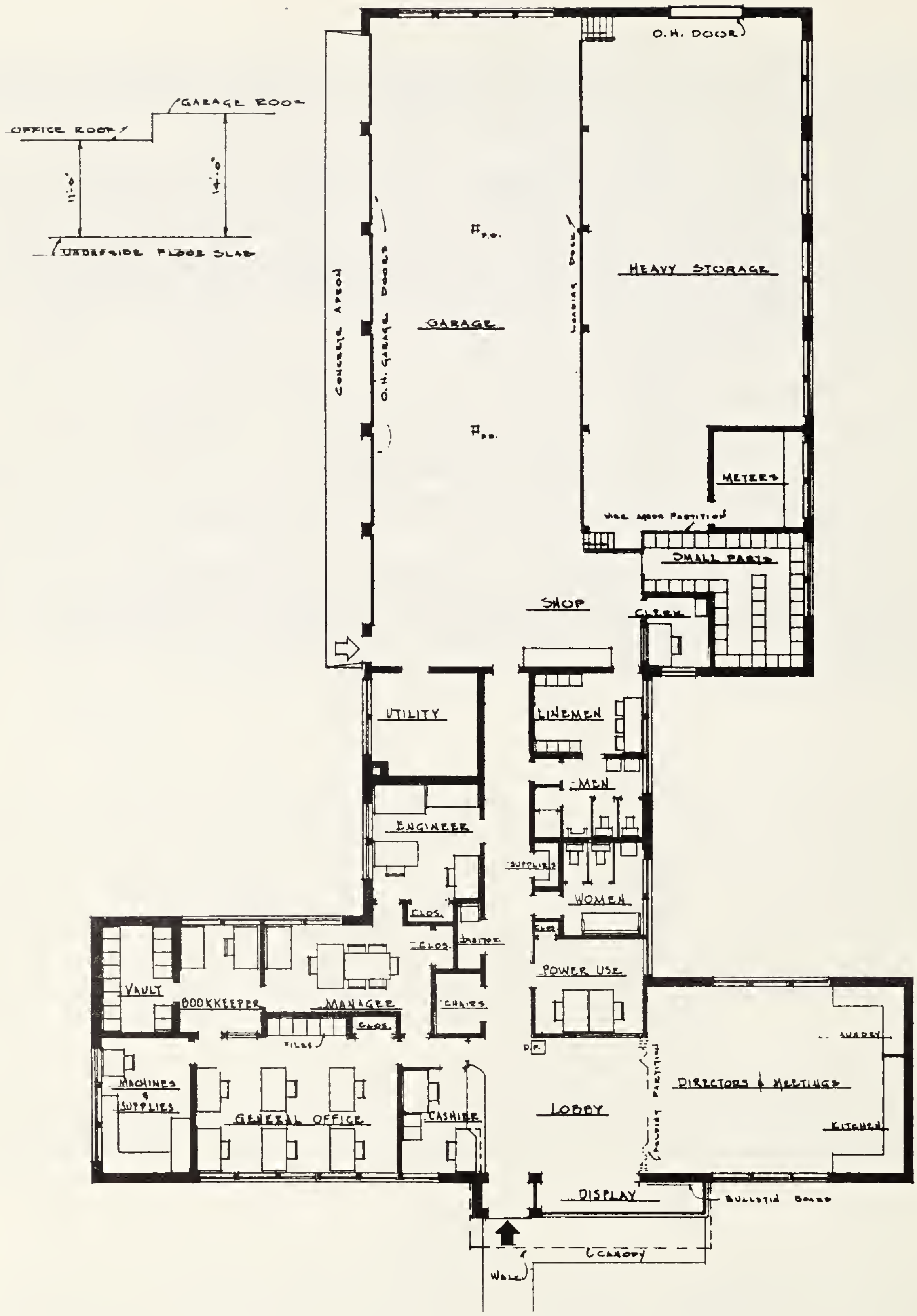


Fig. 1 Typical Layout - Headquarters Building

DISCUSSION
of
TECHNICAL CONFERENCE FOR
REA FIELD ENGINEERS (ELECTRIC)

Held

January 17 - 21, 1955

Morrison Hotel
Chicago, Illinois

This Discussion, the Program and the Conference Papers previously distributed comprise the complete "Proceedings of the Technical Conference for REA Field Engineers (Electric), January 17-21, 1955."

RURAL ELECTRIFICATION ADMINISTRATION • U. S. DEPARTMENT OF AGRICULTURE

DISCUSSION OF GEORGE K. DITLOW'S PAPER
"A REVIEW OF OPERATIONS ON MAINTENANCE
SURVEY REPORTS"

E. L. Florreich, Field Engineer, Southwest Area: Comments and observations on reports analyzed during past year on page 7 of paper and in order shown:

1. Between 3 to 5 days to be spent on average size cooperative, and at least two days spent in preparing the report.

2. Am of the opinion the REA field engineer should prepare the Form 300; because it appears cooperative personnel exaggerate condition of system in a direction towards being better than it is.

3. For reports to indicate lines inspected, age and location will slow down and require more time and work than benefit derived. Such record is not easily obtained, and would in many cases be inaccurate. The writer attempts to observe as great a quantity of distribution line which is above ground line in areas of different terrain that will represent a good sample of the whole system without regard to age. Also, writer prepares a key map of lines observed by marking with red crayon. This map indicates to field engineer the size of sample.

4. Information with regard to miles of line in section being evaluated which is requested on Form 300 is misleading. It appears to the writer that the field engineer is evaluating the whole system from the sample he observed. Such is the interpretation of all SO&M surveys made. Usually the quantity of lines observed is noted in the body of the report.

5. I would like to know what specialties of field engineers are reflected in the reports in order to determine if I am an offender.

6. Have not reviewed any systems that have had previous inspections which compare with those presently being made; but surely the field engineer should be supplied a copy of previous surveys.

7. Noted.

8. Noted, and type terrain should be reported and include climatical conditions.

Comments on questions on page 8:

1. The size of the system should have a bearing upon time to be spent on a project, and has upon systems that have 4000 miles of lines or more. Since in accordance with present procedure it a requirement to evaluate operation, maintenance, replacements and system improvements for a two year period. Usually it requires as much time to determine this evaluation as it does to determine it for a period of 5 or 10 years, the time to do this is the same for a small system as a large one.

2. In general, borrowers are cooperating and supplying information requested in REA Bulletin 161-5R1.

3. Rating the condition of a system will in my opinion always reflect the opinion and judgement of the individual preparing the SO&M report.

4. I doubt that it is necessary that Form 300 result in a compromise. If the field engineer prepares and signs the Form 300, it should be his right to differ with manager and cooperative personnel in the evaluation; but include the others opinion in the body of the report on items where there is difference in opinion and evaluation.

5. At this time it appears not necessary to place more emphasis to older portions of the system during inspection except probably where it is evident extensive maintenance is required. Since poles are one of the most costly items of maintenance and replacement, some of the older poles are probably better than poles obtained in 1947-48 and 49.

6. With no more field engineers than are available now, there appears nothing can be done to improve scheduling of the general inspections.

7. Form 300 appears to be satisfactory.

Comments on paragraph one on page 9:

"The contents of this paragraph appears to give a thought entirely contrary to my interpretation of REA Bulletin 161-5R1. I am surprised to hear that the primary objective of the General Inspection is the review of the physical plant. If this is REA policy, the field engineer need only report on items 1, 7 & 8 listed under Article V, Summary of General Inspection. I am of the opinion that to limit the General Inspection to the objective of determining the condition of physical plant would be a serious mistake. Not so long ago, REA was having difficulty obtaining borrower's management to recognize the need of maintenance and good operation practices. Many still do not have good or adequate records. In general, I find the borrowers receptive to the General Inspections, and appreciate advice and comments made with regard to improvement in maintenance and operation practices. I am not sure that the existance of the review of systems in the future has effect in borrower's management initiating better operation and maintenance practices. Should this policy with regard general inspections be curtailed as is suggested, REA will lose a worthy tool to have such systems put into adequate condition; will reduce the value of REA's loan security; and could be detrimental to the entire program.

"If it is a serious problem that all REA borrower's systems be inspected soon or in the near future, REA should find some method to employ more field engineers, at least until one general review is made of each system. I could not recommend that the quality of such inspections be reduced or curtailed."

Howard S. Willard, Field Engineer, Northeast Area: Is there any particular objection by REA of having both the manager and the field engineer sign Form 300 which is to be included in the O & M Survey Report?

George K. Ditlow: Mr. Florreich's comments on the time spent confirms experience of others that approximately 4 days time is appropriate for the field work and that about 2 days time is necessary to write the report. We conclude from his comments that the time necessary for a review is not proportional directly to the size of the system.

We agree that the field engineer should submit his own appraisal on Form 300 as being more information for REA purposes. This should answer the question raised by Mr. Willard.

Mr. Florreich's comments with regard to considering age of the lines at this time is consistent with our opinion. In the event that a deficiency is found in any particular group, special consideration should be given to this deficiency.

Regarding his comments on the primary objective of the review, we believe this subject may not be too well understood by many and we feel that perhaps consideration should be given to clarify the matter and to give more precise instructions. We did not intend to convey the thought that comments and advice concerning operations and maintenance should be seriously curtailed. However, we feel that activities along these lines should not be pursued to the extent of adversely affecting the review of the physical plant.

DISCUSSION OF C. J. WALDRON'S PAPER
"FINDINGS OF MATERIALS AND EQUIPMENT
PERFORMANCE SURVEY"

Peter A. Mancini, Field Engineer, Northeast Area: In comparing conductor failures of copper vs. aluminum, has any decision been reached? Present conditions tend to show up aluminum to better advantage. For instance, there are no aluminum (conductors) smaller than #6 copper equivalent where many copper failures occur. Aluminum on the average is newer than copper. On system improvements, many borrowers are going to aluminum on heavy main feeders. Greater care is exercised in the construction of these feeders. Also, many line crews look upon aluminum as something fragile and handle it with far greater care than they would copper.

J. B. Davis, Field Engineer, Southeast Area: Why not mention manufacturers' names in discussing failures in reports distributed to borrowers? This is what some borrowers have mentioned to me as desirable. It would create more interest and result in better reporting. It would also give them some sort of buying guide.

To insure the success of the survey, we must make it more interesting and informative to reporting cooperatives. This is just one of many forms they have to fill out, and we must make them feel that they are getting some benefits, something which will help them do a better job.

Harry Thiesfeld, Field Engineer, North Central Area: I believe some borrowers have stopped reporting -- thinking it was not necessary after the reorganization of REA. A quarterly or semi-annual letter should be written to each borrower relative to his reports or lack of reports.

J. W. Carpenter, Field Engineer, Northeast Area: We now ask a system to make reports for an indefinite period. This is quite a job. Wouldn't it be better to have a rotating list so that we can set a time limit for the individual cooperative participation? By doing so we give them a job they can finish -- not an everlasting one.

L. L. Huff, Field Engineer, Southwest Area: It is my suggestion that each field engineer be assigned one system on which to check equipment performance failure reports each month. It is my belief that 37 borrowers submitting complete detailed reports checked by field engineers would furnish more information than hit-or-miss reports from 212 borrowers.

C. J. Waldron: Some of the reasons that existing data on copper and aluminum conductor failures are not conclusive are given by Mr. Mancini. The limited amount of data on failure rate makes it impossible to indicate the superiority of either copper or aluminum conductor at this time. When comparisons become clearer, it is likely that any apparent deficiencies will be related more to the way in which the conductor is applied than to the capability of the conductor materials. These comparisons will include such factors as conductor tensions, protection at supports and connections, and methods of making electrical connections.

Mr. Davis' suggestion that manufacturers' names be used in our published reports would be applicable for private enterprises. However, it is questionable whether the Government should make comparisons of various manufacturers' products by name in view of its overall responsibilities and the possible difficulty of furnishing conclusive evidence concerning the products of a particular manufacturer. Any data showing poor performance of a manufacturer's product will be brought to the attention of the manufacturer and of the Technical Standards Committees for appropriate action.

To alleviate the problems suggested by Messrs Davis and Thiesfeld, relative to lack or inadequacy of reporting, we are of the opinion that more frequent reports to borrowers on various items in the survey will provide a greater incentive for more complete and accurate reporting. We have under consideration a quarterly or semi-annual letter to each participant summarizing the failures reported by him. Supplementing the reports, these letters would provide additional details for individual participants and stimulate interest in good reporting.

Mr. Carpenter's suggestion that individual borrowers be participants for a limited time would have serious limitations. It would be difficult to systematically rotate borrowers participating in the survey, as considerable time is involved in obtaining suitable newcomers, as well as in training them to do satisfactory reporting.

The geographical distribution of necessary participants in the survey would make it impractical for each field engineer to work with only one borrower, as suggested by Mr. Huff. It is expected that some changes will be made in the present distribution. From a statistical standpoint, a 10 percent sample should be a satisfactory number. More experience may indicate five percent to be enough. At present it is necessary to have more than 10 percent of our borrowers in the survey, because of the lack of historical data.

DISCUSSION OF J. N. THOMPSON'S PAPER "RECENT ACTIONS OF THE TECHNICAL STANDARDS COMMITTEES"

Howard S. Willard, Field Engineer, Northeast Area: What consideration has been given by REA for placing the Hubbard 18 inch neutral offset bracket on the Approved List of Acceptable Materials? There is need of such equipment in ice, sleet and snow country especially in the New England and New York areas.

James B. Davis, Field Engineer, Southeast Area: Why are not bridle type deadends approved for ACSR cable? When specifications are revised, or new ones issued, give us more details as to why. We need a specification on installation of Kyle Type R reclosers, both for substation and pole mounting.

Peter A. Mancini, Field Engineer, Northeast Area: REA has apparently approved a 720 cycle water heater control device submitted by General Electric. What are the advantages and disadvantages of this over the clock type control, and to what extent does REA recommend its use?

E. L. Florreich, Field Engineer, Southwest Area: Previous to attending this conference, it had been suggested by one borrower and one consulting engineer that I suggest that REA provide an approved specification for multiple services taken off one pole, particularly in small city distribution systems.

J. N. Thompson: The neutral bracket described by Mr. Willard has been submitted by the manufacturer for observation and comment. (See Figure 1.) It is essentially a very long double upset bolt which holds the neutral at a distance from the pole to minimize conductor contacts during the dropping of sleet or snow loads. A reinforcing strap adds considerable strength vertically but very little in the horizontal plane. Tests indicate that the bracket will bend under a load of between 200 and 250 pounds applied longitudinally (to the conductor) in the conductor groove. This does not meet the requirements of paragraph 261 E 1(a) of the NESC which states:

> "GENERAL. Pins and ties and other conductor fastenings shall have sufficient strength to withstand an unbalanced tension in the conductor, up to a limit of 700 pounds per pin or fastening."

Although the bracket offers a simple and economical way to offset the neutral, its failure to meet or approach Code strength requirements seems to preclude its acceptance by REA. It is our impression that present thinking in REA leans toward horizontal construction in such areas in spite of its additional cost.

Until recently our construction drawings for the deadending of service cable called for the same method used on neutrals and bare secondary conductors. This method uses two loop deadend clamps at each deadend in order to develop substantially the rated strength of the ACSR. The bridle type clamps referred to by Mr. Davis were not considered acceptable because their holding power on the ACSR is only some 60-80 percent of the rated conductor strength. Recently Technical Standards Committee "B" took action to change the standard deadend for triplex to allow the use of one rather than two loop deadend clamps. It now seems to be in order to reconsider some of the patented bridle type deadends which are on the market.

We are planning to make tests on these before considering them for listing, but we do not know just how soon this can be done.

When the Kyle Type R recloser was introduced, we expected few borrowers would purchase them and that installations would be "custom made" to fit the particular requirements of the location. As it has turned out the interest of our borrowers in this recloser has been much greater than either we or the manufacturer had expected. The need for standard specifications for installation is recognized and it is hoped that drawings will soon be available.

Three makes of centralized water heater control equipment have been considered by the committees. Those manufactured by the General Electric Company and the Northern Engineering Company have recently been given general acceptance and listing. The equipment made by the Control Corporation is still on trial acceptance but an application for general acceptance is pending committee action at this time (February 15, 1955).

Mr. Mancini questions the relative advantages and disadvantages of this type of equipment as compared to the time clock controls. The greatest advantage of the centralized control is its flexibility. It can be actuated by demand meter or by ammeter as well as by master time clock or manually. It can be adapted to fit almost any daily, weekly or annual fluctuation in load factor as well as to take care of emergency conditions. Its disadvantages are greater first cost and maintenance expense. The relative weights of these advantages and disadvantages can be evaluated only for individual installations and only after a careful study of all factors including wholesale and retail power rates, load factor, shape of load curve, saturation of water heaters and other items. REA does not make any general recommendations regarding the use of centralized control or time clock control because identical conditions cannot be found on any two systems or even on two substations of the same system. The listing of a load control system in the list of materials does not carry the authorization for its purchase by any borrower. The equipment should not be purchased without prior approval of the Area Director.

The problem of multiple service takeoffs noted by Mr. Florreich is one which seems to concern very few borrowers. It is recognized that it is quite difficult to attach more than two service conductors to the same spool, whether on service rack or clevis. Moreover, if additional clevises or racks are used the pole is weakened from so many holes.

Some time ago Porcelain Products, Inc. submitted to the committee a spool insulator which is designed to take care of this problem. (See Figure 2.) The committee decided not to list the item at that time because it was felt that the limited need for it by our borrowers would not warrant its inclusion in the list. No other objection was raised. We would suggest the use of this spool which can be supported either in a secondary swinging clevis or in a service rack which is suitable for secondary spool insulators. The No. 11357-B, which has a steel reinforcing band is recommended rather than the No. 11357 which is not reinforced.

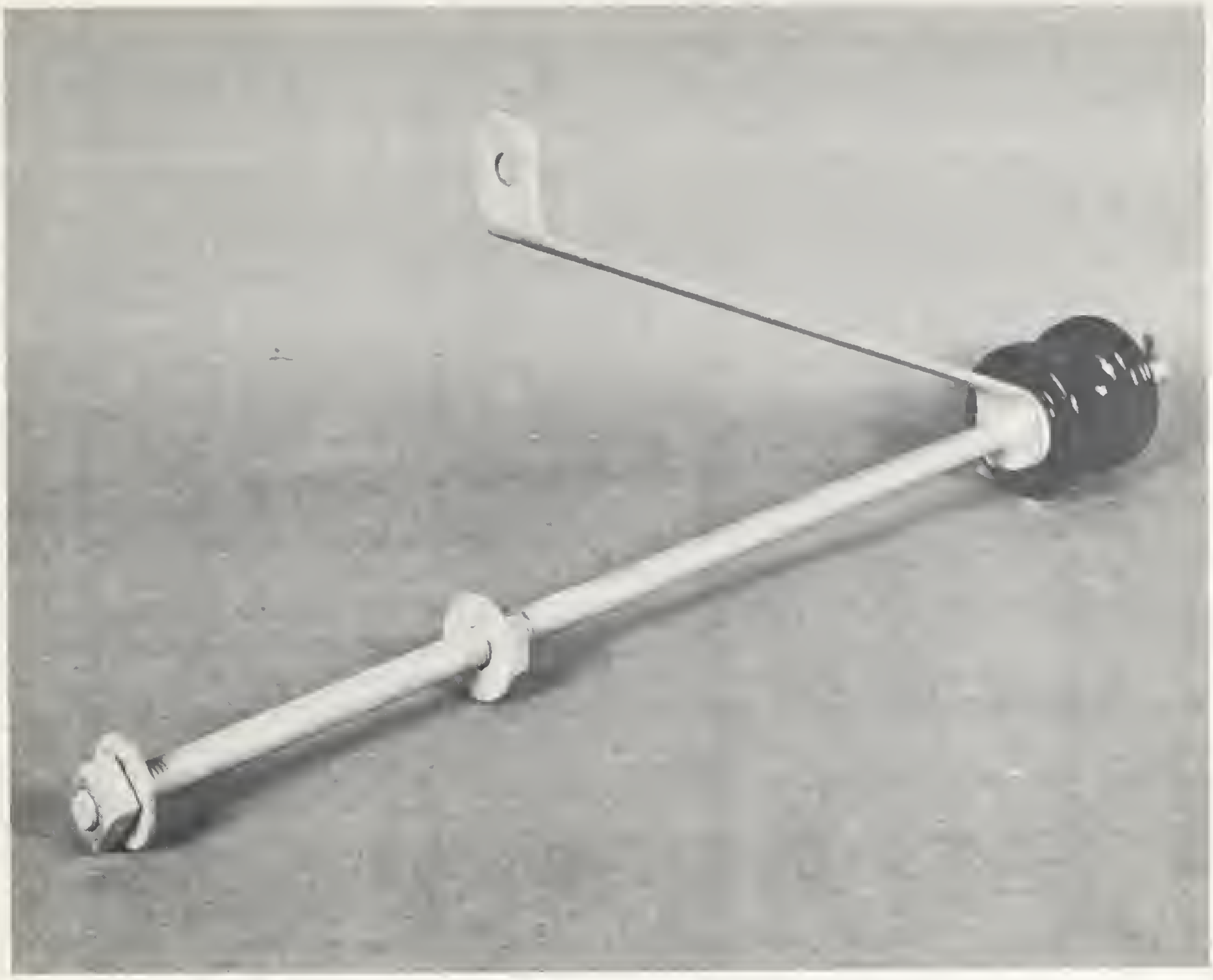


Fig. 1. Offset neutral bracket

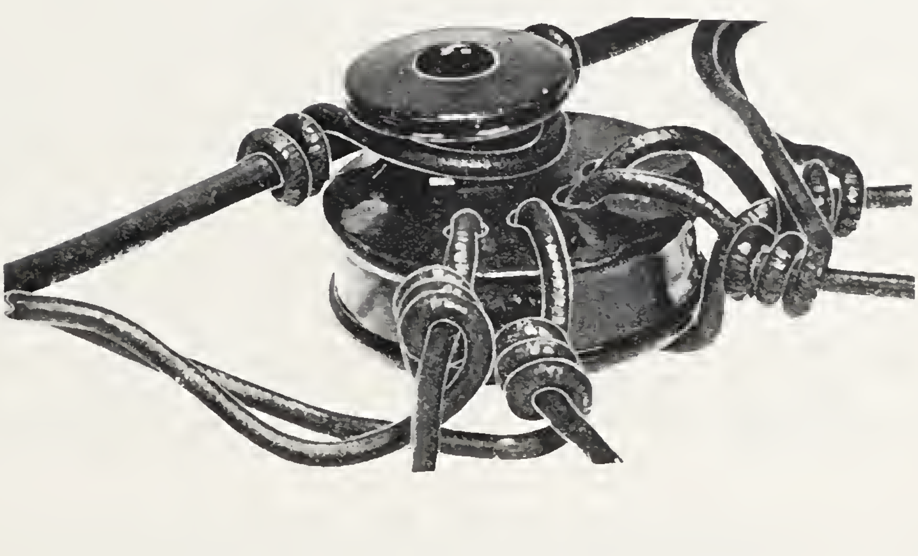


Fig. 2. Multiple service takeoff spool

DISCUSSION OF C. H. AMADON'S PAPER
"POLE INSPECTION AND MAINTENANCE"

J. H. Phillips, Field Engineer, Southeast Area: Should not REA adopt a policy against supply houses such as Graybar, Hughes, General Electric, Westinghouse, etc., supplying crossarms to cooperatives, and require crossarms to be supplied direct from treating plants?

It has been my experience that these supply houses will ship any crossarm in stock, regardless whether or not it has received REA inspection. It is exceptional to obtain inspected crossarms from these supply houses. I don't know the answer to this, but I believe that if we adopted a policy against their acting as crossarm suppliers, it might cause them to get their respective houses in order. We would then be in a position to change our opinion of them with respect to this matter.

In discussing the treatment penetration of fir crossarms with the Joslyn people, they have indicated that they would furnish our field engineers a cutaway 4 foot sample of a 6 pound penta treated fir crossarm, if requested to do so. Such a sample has been promised to me so that I can show cooperative managers that penetration of fir can be obtained. I intend to chisel off the Joslyn brand as I don't wish an implication that I am a Joslyn salesman. If other field engineers would let Joslyn know that such samples were wanted, I am sure they could get them.

Peter A. Mancini, Field Engineer, Northeast Area: There is a belief in the field that REA is discontinuing certified pole stocks. There is concern among some of the suppliers and borrowers because they claim it will result in higher pole prices and slower deliveries. If true, is the termination of certified stock being considered?

My second question is: Why is REA opposed to incising crossarms?

C. H. Amadon: Mr. Phillips' question appears not to imply a poor quality of delivered product, but rather a loose practice in supplying crossarms which may not have been inspected by REA. However, it does not seem advisable to adopt the suggestion, until it has been conclusively shown in an individual case that non-specification crossarms have been furnished to an REA borrower.

In answer to Mr. Mancini's first question, discontinuation of certified stock is only the possible end result of considerations that are now being given to the whole problem involved in maintaining such stocks. The difficulties of insuring adequate surveillance of the stocks at the many plants which might desire to maintain them, and, of assuring delivery of satisfactorily inspected poles, are such that a whole new procedure is being developed. When this new procedure has been formulated the plan will be submitted to interested parties involved in the plan, for comment and suggestions. These will be fully considered and if the plan is put into effect, maintenance of authorized stocks will be continued. If no adequate procedure appears feasible then authorization to maintain certified stocks may be withdrawn.

Referring to Mr. Mancini's second question, neither Specification DT-5 (and EEI Specification TD-90), for electric system crossarms, nor REA Bulletin 345, for telephone system crossarms, prohibits incising of crossarms. Nor does either specification permit incising.

Incising is a means for facilitating penetration of preservative into wood that normally resists penetration. In large part it is a means for taking advantage of the facility

with which the preservative moves longitudinally in the wood fibers as distinguished from the movement transverse to the wood fibers. Incising can only increase penetration through the lengthwise surfaces of the crossarm, as distinguished from penetration into the ends of the arm and into the wood at each of the bolt and pin holes.

Incising would not be of any material benefit in southern pine crossarms. It is useful in treating Douglas fir timbers such as ties, structural joists, beams and the like, where the exposure to decay conditions may be severe. Douglas fir crossarms, however, are used where decay originating externally is very unlikely, except in the contact surface between the arm and the pole on which it is placed. Hence,overall treatment has not generally been considered economical.

However, in some localities decay originating in pin and bolt holes of untreated fir crossarms has materially shortened the service life, and in view of high first costs and labor costs for installation (and replacement) treatment of fir crossarms is now considered essential.

Fir crossarms are commonly treated by either non-pressure or pressure processes the latter process being specified for REA crossarms. The required penetration is $1\frac{1}{2}$ inches lengthwise from the ends and from pin and bolt holes, and complete penetration of any sapwood. The depth of penetration (from the surface) usually obtained in a treatment that results in the specified penetration (from the ends and from the pin and bolt holes) is, on the whole, satisfactory protection against external decay.

DISCUSSION OF E. J. RAUSHENBERGER'S PAPER "INTERNAL COMBUSTION ENGINES AND THEIR USE IN GENERATING ELECTRIC POWER"

Harold P. Leary, Field Engineer, Western Area:

1. How is the best way to remove the practically solid diesel fuel from the fuel tanks, even in warm weather, if it cannot be pumped as it is too thick to run out?

2. What is the best method of time checking in a small generating plant? What are the relative costs?

3. What recourse has a cooperative to the manufacturer if their units have not met the performance tests which they guaranteed?

4. Are detergent oils recommended for lube oil in diesels?

5. Since the REA Field Engineers are to be responsible from an engineering viewpoint for generating plants, what REA bulletins do you recommend be reviewed in order to familiarize himself with them?

E. J. Raushenberger:

1. A liquid will flow so as to adapt its shape to any vessel containing it. The rate at which a liquid accommodates itself to a change in shape is influenced by its viscosity, or the friction between its molecules. All fluids, liquid or gaseous, have the common characteristics of yielding to any force no matter how small. The rate they yield, or flow is controlled by viscosity. This technical definition differs from the dictionary definition of viscosity as "thick, glutenous, sticky," etc.

Viscosity of fuel oils is a measure of ease of flow. It is commonly expressed in Saybolts Second Universal at 100° Fahr. Fuel oils with a viscosity not in excess of 2000 S.S.U. @ 100° F, can be pumped. Certain residual oils require heating or blending with oils of lighter viscosity to reduce the viscosity of the residual oil within the range for ease of pumping. Usually immersion heaters using steam or electricity are placed within the discharge outlet of the tank to heat the oil. It requires about .5 BTU to raise one pound of oil, one degree Fahr. In the field heat is generally used to control viscosity rather than blending.

2. The necessity for controlling frequency on systems using isolated generating plants is usually to provide a means for consumers to use electric clocks with reasonable accuracy. In such plants a synchronous clock with a sweep second hand and a dial of approximately 12 inches in diameter is connected to the station potential bus. Installed beside the electric clock is a similar mechanical clock of precision quality. The mechanical clock is regulated to correspond with the Arlington time signals. The operator, by controlling the speed of the prime movers, can keep the second hands of the electric clock in time with the precision mechanical clock. Such an installation should cost about one hundred dollars.

The Telechron "Type B" master clock incorporates within a single case the movements of the pendulum clock and synchronous motor which regulates a single index hand. This hand records the difference in time between the two movements. The operator adjusts the speed of the prime movers to keep the index hand at zero. Such an installation should cost about four hundred dollars.

Frequency must be controlled within accuracy of about one-twentieth of a cycle in interconnected systems serving industrial loads using a synchronous motor of large horsepower as their speeds vary directly within proportion to the frequency. Much more elaborate equipment is installed to permit control of frequency in such systems.

3. It is assumed that "recourse" refers to legal rights of the cooperative under contractural agreements with the manufacturer. The recommended REA contract Form 200, Generating Plant Construction Contract contains provisions for defective workmanship and materials, as quoted:

> Notwithstanding the acceptance of workmanship, materials, supplies or equipment or the giving of any certificate with respect to the completion of the work, if during the construction or within one year after such completion, or within such longer period as the Project or any part thereof may be guaranteed by other provisions of the Agreement or the Specifications, the workmanship, materials, supplies or equipment shall be found to be defective or not in conformity with the requirements of the Specifications, the Bidder will remedy or replace such workmanship, materials, supplies or equipment within thirty (30) days after notice of the existence thereof shall have been given to the Bidder by the Owner.

The cooperative under such provisions has the rights, if it so desires, to reject the acceptance of equipment as being not in compliance with the specifications. With the proper specifications the cooperative seldom is required to exercise its right under such provisions.

4. Recent trends are to increase the horsepower ratings of diesel engines without increasing the size or weight. Engines are being turbocharged for the purpose of crowding the maximum amount of useful power out of an engine. Further, engine speeds have been stepped up in the universal effort to secure even greater output. These and other changes in design and service have caused a marked increase in the tendency of many engines to form deposits- gum, varnish, sludge and excessive carbon, which interfers with the proper operation of engine parts. Most troublesome engine deposits are caused by contamination of lubricating oil in use by: (1) dust and dirt which enters the cylinders with the intake air, and fuel soot and carbon that blow by the piston rings; (2) oil oxidation products caused by excessive heat and agitation of the oil in the presence of oxygen.

To aid in correcting such deficiencies, most refiners have marketed the so called "Heavy Duty Oils". Such oils usually consist of selected crudes which the unstable hydrocarbons have been removed and to which additives are introduced to insure trouble-free operation in diesel engines. Most additives are multifunctional. However, the additives most commonly used in diesel lubricating oils may be grouped as follows:

1. Detergent-Dispersant
2. Anti-Oxidant
3. Anti Bearing Corrosion
4. Anti Foam

When additives may be used in lubricating oils to impart properties necessary to meet specific service and operating applications include pour depressors, viscosity index improvers, oiliness or anti-wear agents, extreme pressure agents and rust inhibitors. In general, the more severe the operating burden placed on lubrication oil, the higher is the additive content required to provide satisfactory operation and hold down maintenance costs. The prime factors which govern the choice of lubricating oil types are as follows:

1. Engine manufacturers' recommendations
2. Engine design and construction
3. Fuel
4. Maintenance conditions
5. Operating conditions

It should be apparent that lubricating oil for diesel engines should be selected based upon technical requirements rather than sole economic considerations.

5. This question raises several important considerations which are not now covered by existing staff instructions. These matters are now receiving consideration. A staff instruction will be issued defining various field engineer responsibilities.

ERRATA

First word, line four of page 2 should be "hot" instead of "not". Thence, the sentence reads: The temperature may be hot enough to self ignite the mixture before the end of the compression stroke.

The numbers on figure 2 and figure 3 should be interchanged to be consistent with the reference in paragraph 5, page 1.

DISCUSSION OF ROLAND W. SCHLIE'S PAPER "GUIDE FOR MAKING VOLTAGE MEASUREMENTS ON RURAL DISTRIBUTION SYSTEMS"

Henry M. Alford, Field Engineer, Southeast Area: From the discussion this morning, it is evident that we are faced with cooperatives having on hand recording and indicating meters which have lower accuracies than it is felt are necessary to obtain good results from surveys. Thus I feel that information on meter accuracy and why it is important should be disseminated to cooperatives and engineers. A memorandum which discusses this matter fully to those concerned is advisable. May I suggest pictures of the socket-recording voltmeters, ammeter, etc. be added to paper, especially the three-socket test device.

Roland W. Schlie: I am in agreement with Mr. Alford's first statement. It should also be stated that the meters now owned by cooperatives are not obsolete or useless. The List of Materials Acceptable for Use on Systems of REA Electrification Borrowers contains a list of meters under General Plant Section III. All meters on this list are grouped with reference to their application. It is believed that most of the meters now owned by the cooperatives are in Group III. Also, it is believed that a surplus of Group III instruments does not exist. It should be emphasized that there is a definite need by the cooperatives of Group II meters.

Mr. Alford's second statement concerning information on meter accuracies is well taken. I recommend that such information be disseminated as suggested.

With reference to Mr. Alford's third statement, photographs of the socket-recording type were not included since to do so would have included too many photographs of one manufacturer's meters. Figures 1 through 4 have been included in the discussion for your information.

Fig. 1 Three-socket Test Trough Installed in Meter Socket

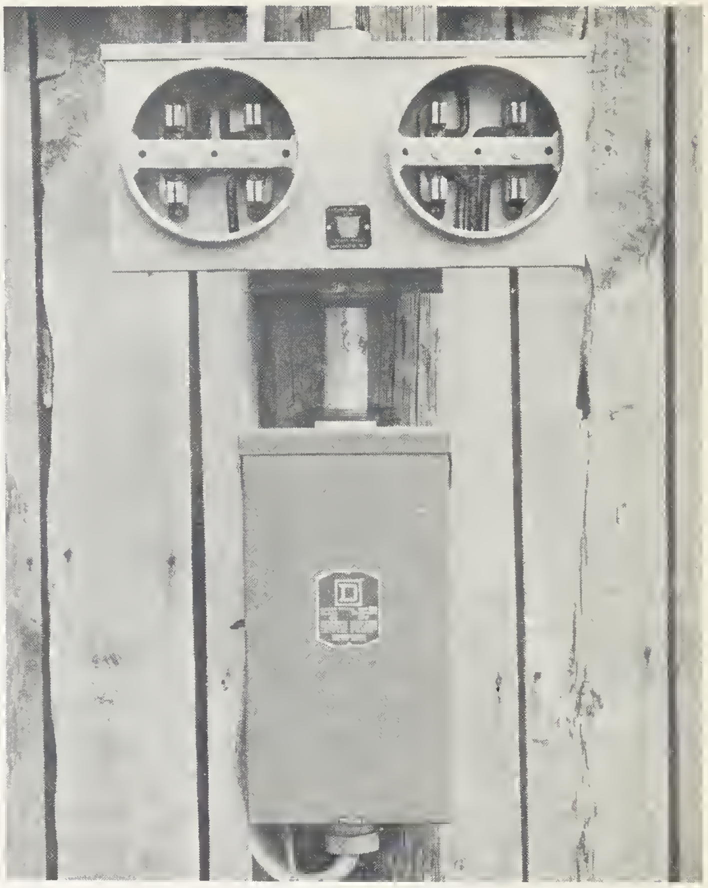


Fig. 2 Two-socket Test Trough Installed in Meter Socket

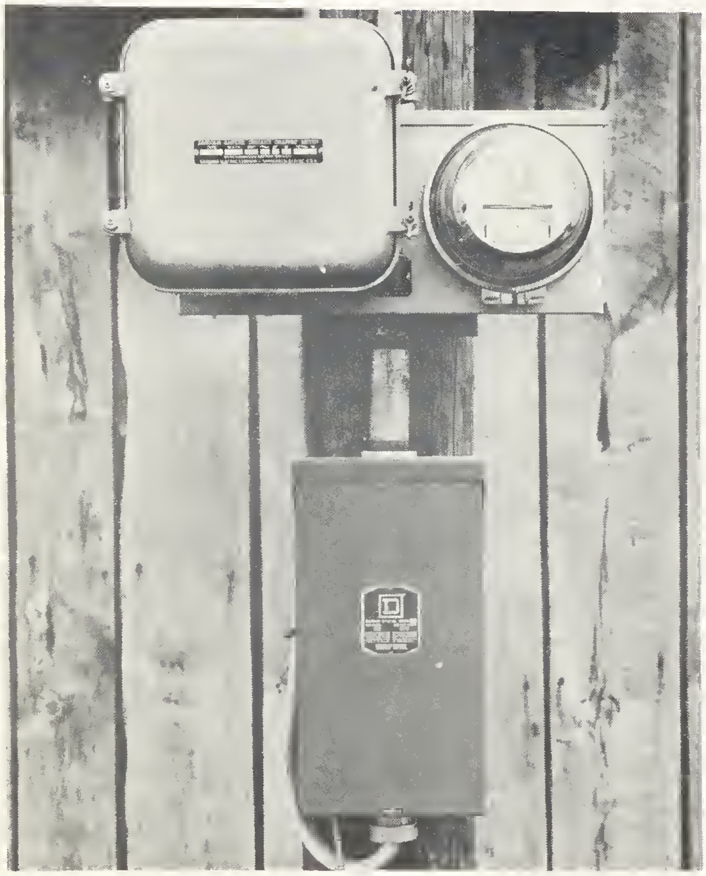


Fig. 3 Three-wire Graphic Ammeter Installed in Two-socket Test Trough

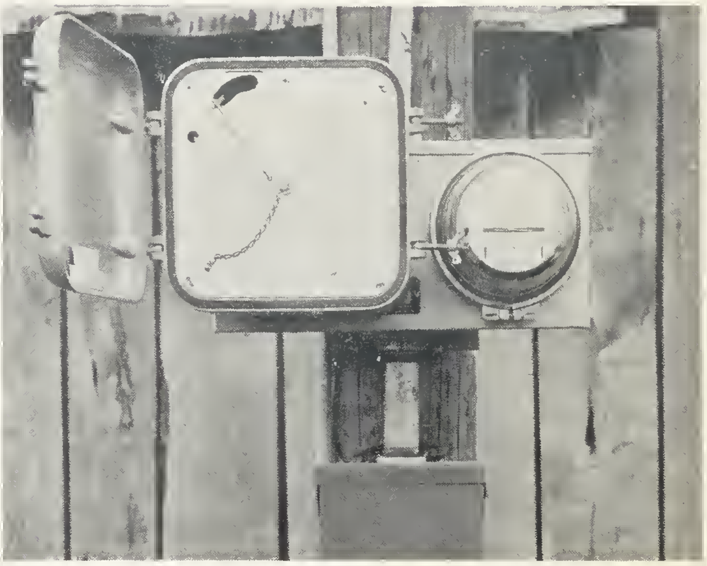


Fig. 4 Three-wire Graphic Ammeter Installation Showing Circular Chart

DISCUSSION OF HAROLD W. KELLEY'S PAPER
"SELECTION OF METERING FOR WIDE RANGE APPLICATION"

Henry M. Alford, Field Engineer, Southeast Area: May I suggest a schematic transformer wiring diagram (Primary and Secondary) be shown on drawing A-3590 (M8-7).

Harold W. Kelley: In the proposed revision of transformer drawings, the schematic diagrams will be shown. Before Committee "A" at the present time is Construction Drawing B-3482 for three-phase transformer bank connected for three-wire, three-phase power. This drawing contains the schematic and refers to A-3590 (M8-7) for metering connections.

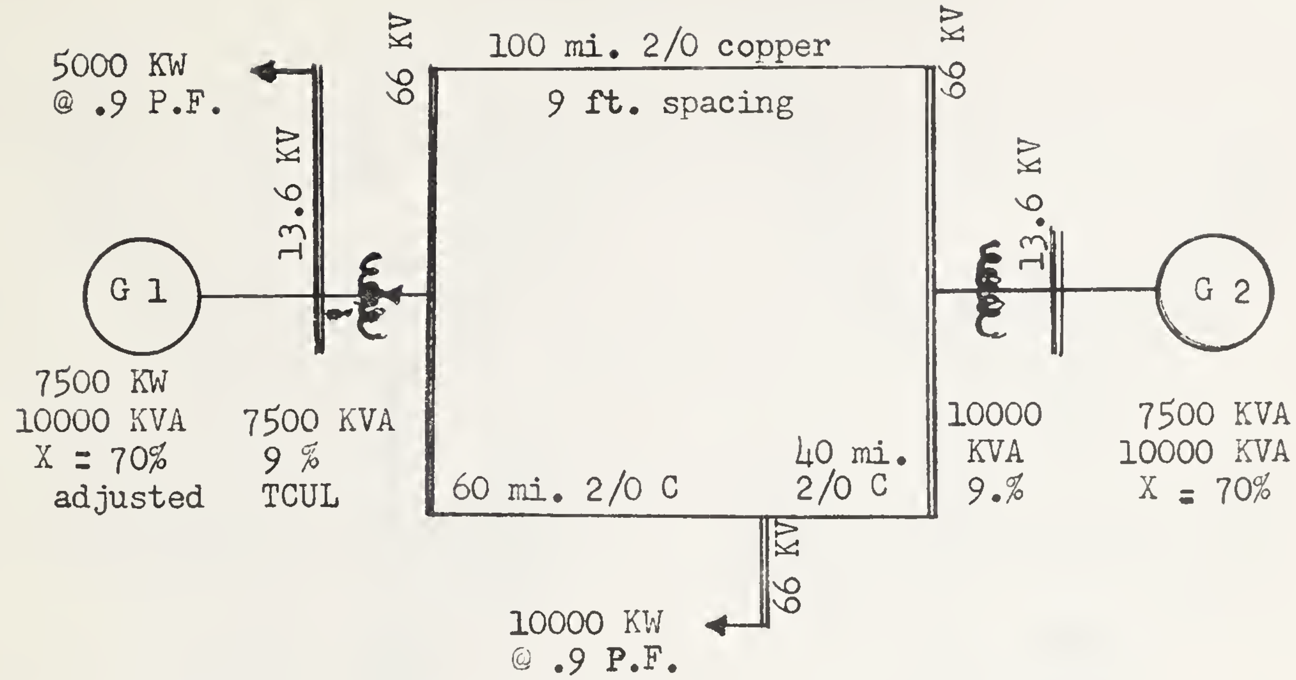
DISCUSSION OF JOHN G. HIEBER'S PAPER "D.C. AND A.C. CALCULATING BOARD"

There being no written discussion offered, the author presents the following closure, based on oral discussion presented at the meeting:

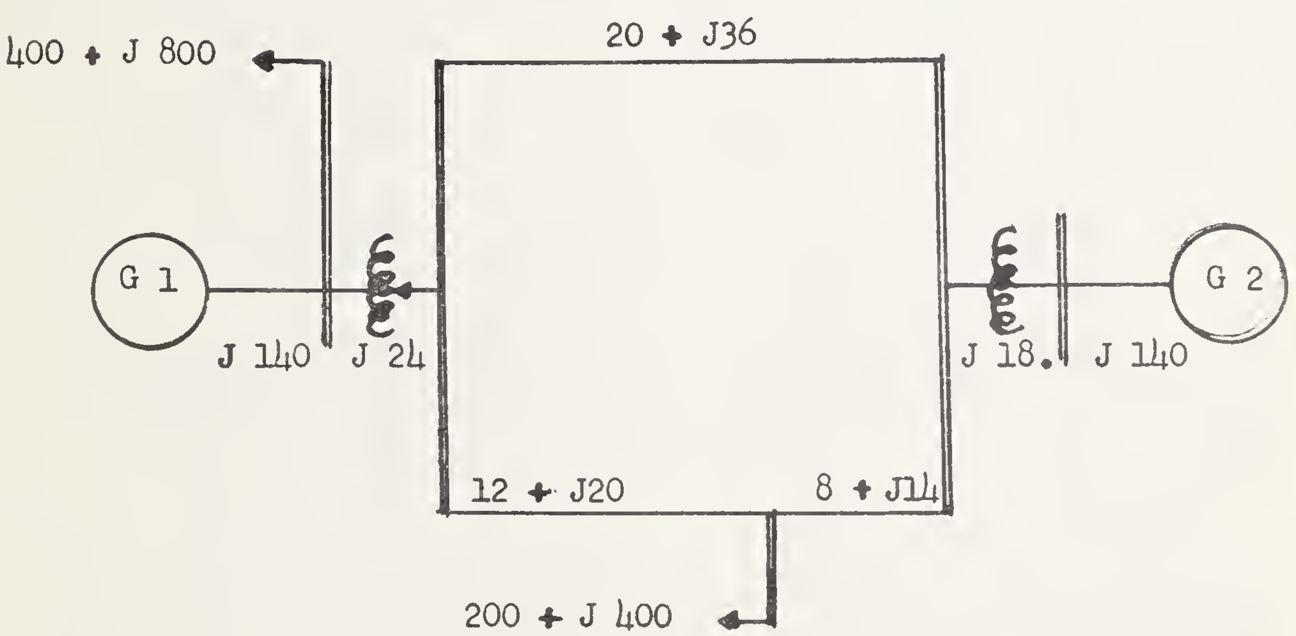
John G. Hieber: Most of the REA borrowers' transmission systems are solidly grounded through a delta-wye step-up transformer. The amount of ground fault current is determined by the impedance of the faulted line from the point of fault to the source of the ground current, the resistance in the fault (including the arc, if any), and the impedance of the ground return path. Arc resistance is a variable factor whose magnitude is determined by the length of the arc and the current through it. The impedance of the ground return path is nearly a constant on circuits having an overhead ground wire, while on circuits where the ground current must return through the earth large variations may occur. The impedance of the earth return path is determined by the conductivity of the soil over which the line is built and whether the soil is wet or dry. High ground impedance may result in low fault current; the voltage on the two unfaulted conductors will increase above its normal value to ground and the charging current may increase. All the charging current for the two unfaulted conductors returns in the faulted conductor in parallel with the ground return circuit.

Considerable study has been devoted to relaying faulted lines with high arc resistance. In one complicated type of ground relay the designer claims to eliminate the effects of ground resistance by having the relay respond to the reactance component of the indicated fault impedance. Where this problem exists, a careful engineering and economic study should be made. Such a study should include data on impedances of pole grounds and costs for improving them. Most high voltage transmission lines will have sufficient ground current to operate over current type ground relays.

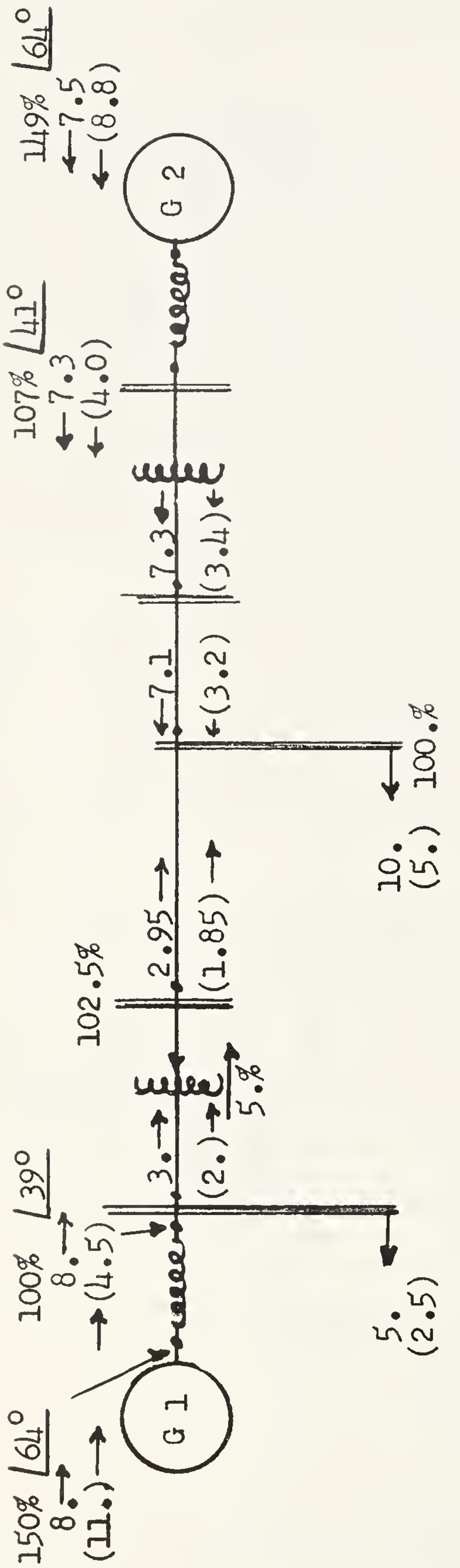
The results of the demonstration on the Illinois Institute of Technology A.C. Board are shown on the following diagrams. Line capacitance (charging KVA) was omitted because the large system study of the Power Company required all available capacitors. Addition of capacitors would have added 25 RKVA leading per mile of 66 KV transmission line. Generator number 1 is overloaded in studies Nos. 2, 3, and 4. The adjustments and readings were taken too hurriedly for highest accuracy.



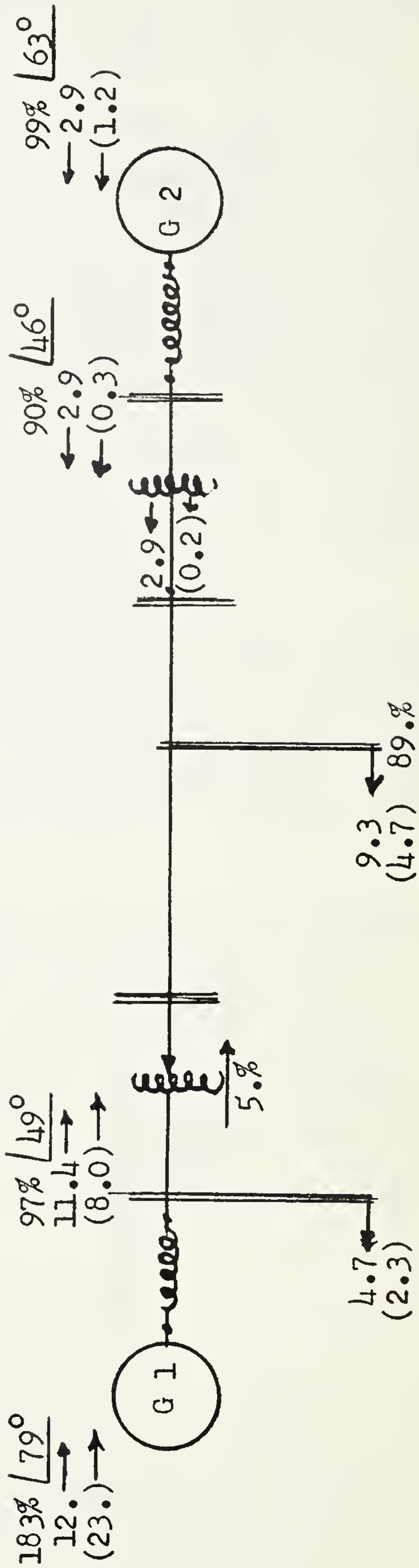
ONE-LINE DIAGRAM OF DEMONSTRATION SYSTEM



PER CENT IMPEDANCE DIAGRAM OF SYSTEM
20,000 KVA BASE



STUDY NO. 1



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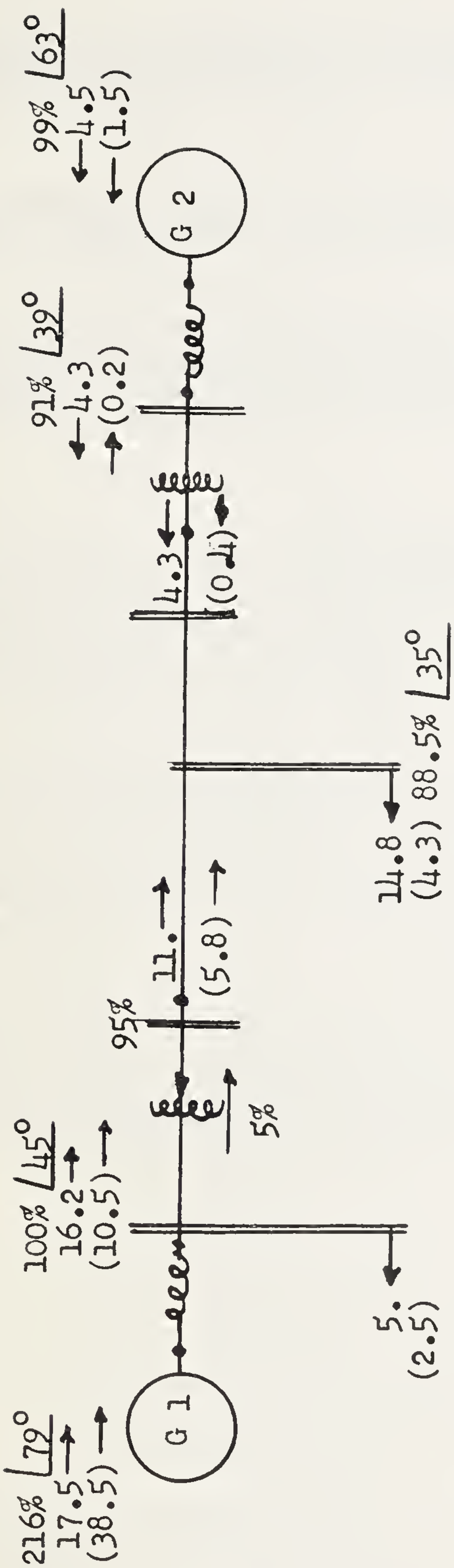

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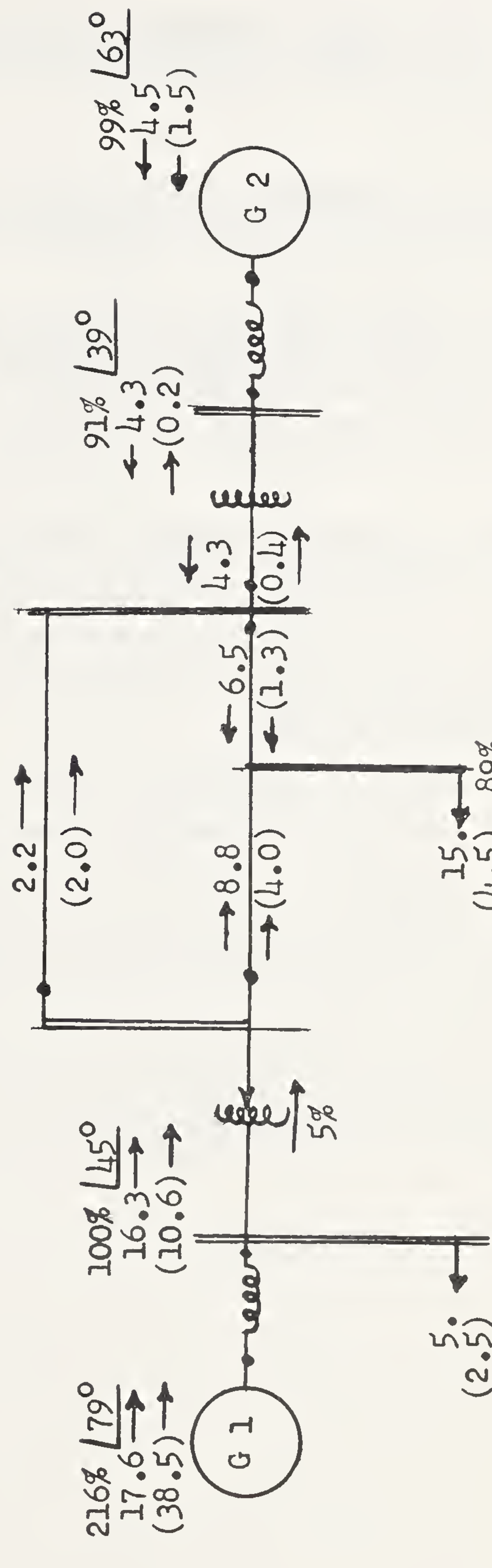

STUDY NO. 4

DISCUSSION OF H. F. MABBITT'S PAPER "HEADQUARTERS BUILDINGS, DESIGN - CONSTRUCTION - MAINTENANCE"

Howard S. Willard, Field Engineer, Northeast Area: What place does the field engineer play in the design, construction and maintenance of headquarters buildings? Do we have a new revised REA Bulletin and Staff Instructions in reference to this matter in process?

H. P. Leary, Field Engineer, Western Area: What part should the field engineer play in the construction of an office building? What REA bulletin and/or staff instruction gives this information?

J. H. Phillips, Field Engineer, Southeast Area: Why should not the Operations' field representative and the field engineer have the opportunity to review with the cooperative manager the preliminary plans for a headquarters building? We field people have gained some definite ideas on building layouts, and I feel certain we could effect some improvements in planning.

James U. Owens who presented paper replying for H. F. Mabbitt: In reply to questions of Mr. Willard and Mr. Leary, there are no staff instructions concerning the field engineer's activities regarding headquarters buildings, and the preparation and issuance of such bulletins or instructions are not contemplated at the present time. However, field engineers should be prepared to aid or participate in design, construction and maintenance problems on headquarters buildings when directed to do so by their area directors.

Regarding Mr. Phillips' question, there is no objection to field representatives and engineers reviewing preliminary plans of headquarters buildings when the opportunity arises. However, a suggestion that the borrower send representatives to visit nearby headquarters buildings which, in the opinion of the field representative contain both good or bad features will, quite often, be of great assistance to a borrower in planning a headquarters building.

We agree with Mr. Phillips in that field engineers do have some excellent ideas concerning the planning of headquarters buildings and the architectural staff would like very much to know more about these ideas. It is suggested that you impart this information to your Area Director so that the ideas can be incorporated into Suggested Layouts so that all borrowers and architects can benefit therefrom.

DISCUSSION OF QUESTIONNAIRE

On the closing day of the conference an evaluation questionnaire was completed by forty-four of the participants. The following is a summary of the replies.

1. In your opinion, do the benefits gained from technical training meetings of this type justify the time spent in attendance?

   Yes (43) No (1)

The reason given by the person who checked "no" was: "Time, yes; cost, no." Reasons given by most of the field representatives who checked "yes" were primarily to the effect that the field engineers do not have the time or the opportunity to keep abreast of new developments and to acquire the type of information obtained at such meetings, and that the meetings serve as a refresher course, boost morale, and enable the participants to perform their work more efficiently. Comments from Washington personnel mostly pertained to the exchange of information between Washington and the field.

2. How did you feel about this meeting? (Check)

   Fair 2 Good 14 Excellent 26 (One paper marked "good to excellent")

3. What were the strong points?

The comments most frequently made by field representatives and Washington personnel in response to question number 3 were: "The manner in which the subjects were presented;" "well prepared papers;" "field trips associated with topic papers and discussion;" "good selection of topics;" "good participation in discussion;" "pole inspection;" and "advance distribution of papers."

4. What were the weak points?

In reply to this question, three persons specifically indicated that they thought there were no weak points while several others did not make a reply of any sort. Nine persons listed hotel accommodations as a weak point. Six persons commented on the lack of time for certain subjects.

5. a. From which topics did you derive the most benefit? (List three, in order of preference)

   Allowing ten points for each time a subject was listed as first choice, 5 points for each time a subject was listed as second choice, and 2 points for each time a subject was listed as third choice, the following is the number of points scored for the top three selections (figure in parenthesis indicates the number of times a subject was listed as first choice): Pole Inspection and Maintenance (25) 281 points; Selection of Metering for Wide Range Application (7) 140 points; Voltage and Current Measurements of Rural Distribution Systems (2) 73 points.

Most of the reasons given for selecting the three topics listed above related to the importance of the subject and to the manner in which the speaker presented the paper.

6. a. Did you read the program material which was sent to you prior to the conference?

   All 17 Some 27 None 0

   b. Do you think such material should be distributed prior to the next meeting?

   Yes 43 No 1 ("Not absolutely necessary")

   c. Suggest anything else that might be done ahead of the meeting to prepare the group.

Most of the comments on this point suggested allowing sufficient time to study program material prior to the meeting.

7. What suggestions do you have for improving methods of presentation?

Five persons said they thought the methods of presentation were very good. Several comments related to better use of visual aids.

8. In which city would you like to have the next meeting held?

Seven persons indicated "no preference" or did not reply at all. Five persons listed St. Louis and five listed Dallas. Other cities were listed by only three persons or less.

9. List the specific subjects which you would recommend for treatment at future meetings. Also list types of field trips, if any, that would be beneficial.

   (Figures indicate the number of times the subject was listed)
   TO&M in general and with respect to specific equipment (10); Poles (8); Transmission systems (5); Conductor (5); Metering (5); Switching and relaying (4); Load dispatching (3); Load trend on co-op lines and methods for recording and collecting data. (3); Transformers (3); System studies (3); Methods of clearing and re-clearing right-of-way (3); Inspection of a conductor plant (3); Transformer loading (2); System protection (2); Trip to meter manufacturing plant (2); and TV interference (2).

10. Other comments or suggestions:

    There was very little consensus on any of the comments that were made. However, three persons commented that some time should be set aside during the conference for meetings with section heads.

ATTENDANCE LIST

Field Engineers

Northeast Area

John E. Case
808 N. Bancroft Street
Indianapolis 2, Indiana

S. B. Holmes
1120 Kelsey Avenue
Lansing 15, Michigan

Howard S. Willard
Box 126
Sheffield, Vermont

J. W. Carpenter
Box 535
Richmond 4, Virginia

Peter A. Mancini
710 S. Clayton Street
Wilmington, Delaware

Magnus Hoye
Room 3860 South Bldg., U.S.D.A.
Washington 25, D. C.

North Central Area

T. D. Essig
904 East Fourth Avenue
Mitchell, South Dakota

G. T. Hall
1801 Bever Avenue, S. E.,
Cedar Rapids, Iowa

H. W. Thiesfeld
Route 3
Mankato, Minnesota

J. M. Henry
P. O. Box 54
Mitchell, South Dakota

C. L. Gran
520 West Vasa Street
Fergus Falls, Minnesota

N. L. Lundeen
744 West William Street
Decatur, Illinois

Lester Windsor
P. O. Box 145
Eau Claire, Wisconsin

Western Area

James M. Garrison
916 North Rodney
Helena, Montana

Andrew J. Herold
P. O. Box 54
Topeka, Kansas

Louis A. Kirkbride
2040 Park Street
Lincoln 2, Nebraska

William J. Hauck
4125 Northeast 79th Avenue
Portland 13, Oregon

Robert C. Holland
9000 West 5th Avenue
Denver 15, Colorado

Harold P. Leary
Route 3
Grand Junction, Colorado

Field Engineers (Continued)

Western Area

Leonard A. Smith
422 South Beech Street
Casper, Wyoming

Clark L. Johnson
2327 So. Grand Avenue
Spokane 8, Washington

Ben F. Wallace
Martin Arms Apartment
Apartment 8H, E. 3rd & Q
Anchorage, Alaska

Southeast Area

Henry M. Alford
P. O. Box 6328
Parkway Station
Jackson, Mississippi

Charles W. Brigham
2325 Redwood Drive
Augusta, Georgia

James B. Davis
P. O. Box 443
Troy, Alabama

Walter A. Davis
533 Twin Oak Drive
Decatur, Georgia

Jennings B. Mabry
P. O. Box 278
Lexington, Kentucky

J. H. Phillips
1715 Glendale Street
Jacksonville, Florida

Southwest Area

Edward L. Florreich
Box 499
Austin, Texas

John P. Hewitt
7715 Prospect Avenue, N. E.
Albuquerque, New Mexico

James L. Higdon
220 Jagoe Street
Denton, Texas

Leean L. Huff
1005 West 2nd Street
Sedalia, Missouri

Horace V. Kain
1100 East Loren Street
Springfield, Missouri

Donald T. Lowery
Box 727
Little Rock, Arkansas

Gilbert F. Moon
3509 So. Richmond Avenue
Tulsa 5, Oklahoma

Ralph L. Shangraw
P. O. Box 386
Safford, Arizona

Clarence R. Wood
Box 391
El Reno, Oklahoma

Clark Reid (OFR)
107 N. Byers
Joplin, Missouri

Myron W. Merchant (OFR.)
302 Santos Street
Abilene, Texas

Washington Personnel

Clarence H. Amadon
Timber Consultant
Electric Engineering Division

Edward L. Arnn
Head, Engineering Section
Western Area Office

Clarence H. Arveson
Timber Specialist
Electric Engineering Division

John F. Atkinson
Equipment and Materials Engineer
Electric Engineering Division

Ivan A. Bosman
Head, Steam Plants Section
Electric Engineering Division

O. W. Briden
Director
North Central Area Office

George H. Cole
Head, Engineering Section
Southeast Area Office

G. K. Ditlow
Systems Operations and Maintenance Engineer
Electric Engineering Division

Wade M. Edmunds
Chief, Northern Region

Robert B. Feagans
Timber Specialist
Electric Engineering Division

John G. Hieber
Transmission Systems Engineer
Electric Engineering Division

Hans Hoiberg
Head, Training Section
Personnel Division

Harold W. Kelley
Meter and Service Engineer
Electric Engineering Division

J. E. O'Brien, Chief
Electric Engineering Division

Walter J. O'Neal
Timber Specialist
Electric Engineering Division

James U. Owens
Architectural Engineer
Electric Engineering Division

Everett J. Raushenberger
Head, Internal Combustion Plants
Electric Engineering Division

John H. Rixse, Jr., Assistant Chief
(Transmission and Distribution)
Electric Engineering Division

W. E. Rushlow
Systems Operations Engineer
Electric Engineering Division

Roland W. Schlie
Distribution Systems Engineer
Electric Engineering Division

Sam Shiozawa
Electrical Engineer
Electric Engineering Division

R. P. Stokely
Head, Engineering Section
Southwest Area Office

James N. Thompson
Standards Engineer
Electric Engineering Division

C. J. Waldron
Systems Maintenance Engineer
Electric Engineering Division

E. E. Warner
Head, Engineering Section
Northeast Area Office

G. L. Woodworth
Head, Engineering Section
North Central Area Office

R. G. Zook
Assistant Administrator